

Subcontractor Report

Texas Bi-Fuel Liquefied Petroleum Gas Pickup Study: Final Report

Y. Huang, R.D. Matthews, and E.T. Popova
The University of Texas at Austin
Austin, Texas



NREL

National Renewable Energy Laboratory

1617 Cole Boulevard
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NREL Technical Monitor: P. Whalen

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Acronyms and Abbreviations

AFV	alternative fuel vehicle
ALVW	adjusted loaded vehicle weight $([\text{curb weight} + \text{GVWR}]/2)$
CFE	combined (gasoline plus LPG) fuel economy in mpegg, from log form data
CFE'	combined (gasoline plus LPG) fuel economy in mpegg, from TxDOT database records
CIFE	combined incremental fuel economy in mpegg, from log form data
CIFE'	combined incremental fuel economy in mpegg, from TxDOT database records
DB	TxDOT database download
FE	fuel economy, in mpg or mpegg
FOC	fuel operating cost, in cents/mile, from log form data
FOC'	fuel operating cost, in cents/mile, from TxDOT database records
FTP	Federal Test Procedure driving cycle; used for emissions certification and determination of urban fuel economy
GVWR	gross vehicle weight rating
IGU	gasoline gallons added in a given month, from log form data
IGU'	gasoline gallons added in a given month, from TxDOT database records
IMD	miles driven in a given month, from log form data
IMD'	miles driven in a given month, from TxDOT database records
IPU	LPG gallons added in a given month, from log form data
IPU'	LPG gallons added in a given month, from TxDOT database records
LDT3	light duty truck (LDV with $3751 \leq \text{ALVW} < 5750$ lb)
LDV	light duty vehicle (GVWR < 8500 lb)
LPG	liquefied petroleum gas
mpg	miles per actual gallon
mpegg	miles per equivalent gallon of gasoline
QVM	Qualified Vehicle Modifier, a Ford program for approved alternative fuel conversions
SGC'	the gasoline purchase price paid by TxDOT
SPC'	the actual LPG purchase price (\$/LPG gallon)
TGC	cumulative cost for the total gallons of gasoline consumed over the project period, from log form data for TGU
TGC'	cumulative cost for the total gallons of gasoline consumed over the project period, from TxDOT database records for TGU'
TGU	cumulative total gallons of gasoline used over the period of the project, from log form data
TGU'	cumulative total gallons of gasoline used over the period of the project, from TxDOT database records
TMD	cumulative total miles driven, from log form data

Acronyms and Abbreviations (concluded)

TMD'	cumulative total miles driven, from TxDOT database records
TPC	cumulative cost for the total gallons of LPG consumed over the project period, using log form data for TPU
TPC'	cumulative cost for the total gallons of LPG consumed over the project period, using TxDOT database records for TPU'
TPU	cumulative total gallons of LPG used over the period of the project (in actual LPG gallons), from log form data
TPU'	cumulative total gallons of LPG used over the period of the project (in actual LPG gallons), from TxDOT database records
TxDOT	Texas Department of Transportation
US06	a high speed, hard acceleration driving cycle; used for part of the Supplemental FTP
UT	The University of Texas
VOLF	vehicle operation log form

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Introduction and Purpose

Alternative fuels may be an effective means for decreasing America's dependence on imported oil; creating new jobs; and reducing emissions of greenhouse gases, exhaust toxics, and ozone-forming hydrocarbons (see, for example, Wu et al., 1998a). The cost effectiveness of alternative fuel vehicles has been examined in several studies (Wang et al., 1993; Herridge and Lambert, 1995; Dardalis et al., 1998). However, data regarding in-use fuel economy and especially maintenance characteristics of alternative fuel vehicles (AFVs) have been limited in availability.

In Texas, one of the most widely used alternative fuels is liquefied petroleum gas (LPG, often referred to as propane). The largest fleet in Texas, operated by the Texas Department of Transportation (TxDOT), has hundreds of bi-fuel (LPG and gasoline) vehicles operating in normal daily service.

This study was undertaken to compare the operating and maintenance characteristics of bi-fuel vehicles (which use LPG as the primary fuel) to those of nominally identical gasoline vehicles. The project was funded by the U.S. Department of Energy (DOE) and managed by DOE's National Renewable Energy Laboratory (NREL).

The project was conducted over a 2-year period, including 18 months (April 1997–September 1998) of data collection on operations, maintenance, and fuel consumption of the vehicles under study. This report summarizes the project and its results.

Project Participants

This project required the cooperation of several participants. Investigators at the University of Texas (UT) conducted the project with technical direction from NREL. TxDOT agreed to participate and allowed the university to collect detailed data on the study vehicles. The General Services Division at TxDOT headquarters in Austin coordinated the data collection efforts between two of its districts and UT, and provided printouts of the computer-based vehicle records that were essential to this project. The two TxDOT districts that took part in the project are located in Houston and Corpus Christi. These two district offices provided fuel addition data and maintenance data for the research vehicles located within their respective districts, and provided access for UT research personnel to acquire other necessary information from their hard copy records.

An initial coordinating meeting was held in Austin, including representatives from TxDOT, UT, and NREL. Two kickoff meetings were held at the district sites, in Houston and Corpus Christi, shortly before data collection began.

The Study Fleet

The project fleet consisted of 35 1996 Ford F150 half-ton pickup trucks with 4.9-L inline six-cylinder engines. Among them, 31 pickups were bi-fueled (15 in the TxDOT Houston district and 16 in the TxDOT Corpus Christi district) and 4 were gasoline-only counterparts used as control vehicles (2 in the TxDOT Houston district, 1 in the Corpus Christi district, and 1 located at UT). Figure 1 shows these locations.

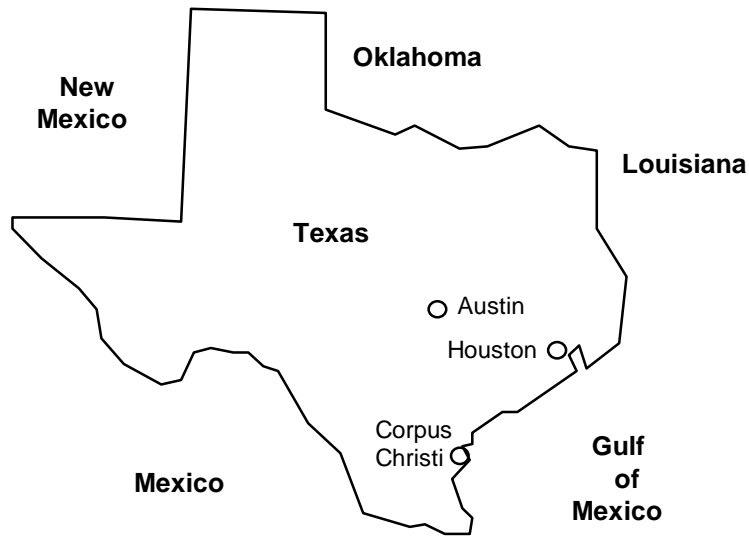


Figure 1. Locations of the district headquarters for the project vehicles: 17 in Corpus Christi, 17 in Houston, and 1 in Austin

TxDOT uses these types of vehicles to transport personnel and light equipment for road design and maintenance, right-of-way acquisition, construction oversight, and transportation planning of state roadways.

The Houston district covers 5,948 square miles, and includes 8,725 lane miles on which 3,262,598 registered vehicles travel 56,158,687 miles daily. TxDOT operates approximately 450 AFVs within its Houston district. The Corpus Christi district, which covers 7,806 square miles and includes 6,796 lane miles on which 394,849 registered vehicles travel 10,140,215 miles daily, operates approximately 131 AFVs.

The 31 bi-fuel research vehicles were Ford F150 pickups converted to LPG using Impco Technologies' mixer systems via Ford's Qualified Vehicle Modifier (QVM) Program (see Figure 2). Table 1 presents the characteristics and specifications of both the bi-fuel and gasoline-only research vehicles.

Data Collection and Evaluation

Three types of data were collected: fuel addition data from vehicle operation log forms; maintenance information collected by UT research personnel from the TxDOT districts and local Ford dealerships that performed warranty maintenance; and records from TxDOT's mainframe computer (fuel addition and maintenance).

Fuel addition data were collected from each driver of each study vehicle. The 34 TxDOT drivers who took part in this project voluntarily filled out a vehicle operation log form designed by UT and TxDOT



Figure 2. One of the F150 trucks used for the project
(photo courtesy of TxDOT)

Table 1. Vehicle Descriptions: LPG and Gasoline Ford F150 Pickup Trucks

	LPG/Gasoline	Gasoline Only
Make	Ford	Ford
Model Code	F150	F150
Body Style	1/2 ton pickup	1/2 ton pickup
Model Year	1996	1996
Model Class	LDV/LDT3	LDV/LDT3
Air Conditioning	Yes	Yes
Fuel System	Bi-fuel	Dedicated
Fuel Tank Capacity (gal)	48 LPG (at 80% full) + 18.2 gasoline	2 tanks: 19+18.2
Fuel System Material	Steel	Steel
GVWR (lb)	6,250	6,000
Engine Model Number	4.9LI6	4.9LI6
Engine	4.9L in-line 6 cylinder	4.9L in-line 6 cylinder
Turbocharged	No	No
Engine Horsepower	145	145
Transmission Type	4-speed automatic	4-speed automatic
Wheel Drive	Rear	Rear

for this project. They had no other obligations to the project. The compliance rate for filling out these forms was quite good except for a few of the drivers in the Corpus district. The vehicle operation log form includes:

- Date
- Mileage at the beginning of the day
- Mileage at the end of the day
- Mileage at the time of refueling

- Fuel added (LPG or gasoline)
- Amount of fuel.

The major source of maintenance data was the TxDOT maintenance file records at the local districts. The following data were recorded:

- Repair order open date
- Mileage when the repair order opened (if applicable)
- Cost of maintenance
- Labor hours
- Category of maintenance (scheduled, unscheduled, warranty)
- Type of maintenance performed.

If a warranty repair was indicated by the TxDOT district records, we visited the local Ford dealerships to obtain labor hours and parts costs. Although warranty repairs are generally done at no cost to the vehicle owner, a few of the vehicles accumulated sufficient mileage before the end of the project to exceed the warranty limit. More importantly, we wanted to extrapolate the costs of the bi-fuel vehicles beyond the warranty period, because TxDOT almost always keeps vehicles beyond this period.

Finally, data were also downloaded from TxDOT's mainframe computer on a monthly basis. This included:

- Cumulative fuel usage
- Cumulative oil usage
- Cumulative vehicle downtime
- Cumulative mileage (last odometer reading).

TxDOT also provided fuel purchase price data for both LPG and gasoline. All collected data were entered into a database on a PC, processed by UT investigators, and submitted to NREL each month. The project started on April 1, 1997, but our initial download from the TxDOT database was in June of 1997. To keep the same time basis for the results from the vehicle log forms and from the database records, the analyses include the data beginning in June, except for some of the fuel economy comparisons, as will be discussed later. The statistical analyses included fuel consumption, scheduled maintenance, unscheduled maintenance (repairs), and reliability of the vehicles being studied.

Fuel Economy, Fuel Operating Cost, and Percent LPG Usage

For LPG and some other alternative fuels, the lower fuel price relative to gasoline represents potential savings to the vehicle or fleet owner. The magnitude of this savings will depend on the relative costs of LPG and gasoline, the percent use of the alternative fuel, and the fuel economy of the vehicle. These factors combine to yield the fuel cost per mile (the fuel operating cost).

During the 18 months of data collection, 2,871 refueling data points were recorded. In addition to the data from the vehicle operation log forms, for each of the vehicles in the project TxDOT provided monthly mileage driven, fuel usage (LPG and gasoline gallons), and oil usage and oil cost records, all downloaded from its database each month. TxDOT also provided the monthly purchase price of each fuel (LPG and gasoline). The refueling data from the log forms are attached as Table A-1 in Appendix A and the corresponding data from the TxDOT database are provided as Table A-2. The results summarized in this section are based on these data.

Examining Tables A-1 and A-2 reveals that both the monthly mileage driven and fuel usage downloaded from the TxDOT database are different from those we extracted from the vehicle operation log forms. This resulted from the fact that the cutoff dates for the TxDOT data processing are different from the direct data collection. Thus, as discussed in more detail in Appendix B, four methods are available for calculating the fuel economy for each of the vehicles in the project:

- Overall (long-term) analysis from the database records
- Overall (long-term) analysis from the vehicle operation log forms
- Statistical analysis of the data on the vehicle operation log forms
- Statistical analysis from monthly database records.

Fuel Economy

All the AFVs studied were bi-fueled. The operators of these trucks used both LPG and gasoline and no attempt was made to track the exact mileage when the operators switched from one fuel to the other. The operators can refuel both LPG and gasoline to separate tanks at each refueling. Furthermore, LPG and gasoline have different energy densities (fuel energy per actual gallon). These factors complicate the determination of fuel economy.

We requested that all operators of the bi-fuel vehicles in the project use LPG exclusively for one month and gasoline exclusively for another month, and many complied. These results yield data sets for the fuel economy for LPG-only for the bi-fuel vehicles and for gasoline-only for the bi-fuel vehicles.

The fuel economy was determined as the ratio of the total mileage driven during the period of use of one fuel exclusively to the total actual gallons (i.e., gallons of LPG rather than equivalent gallons of gasoline) of fuel used. All the data used in these calculations were obtained from the vehicle operation log forms. Table 2 presents the results for these vehicles.

As derived in Appendix B, after accounting for the differences in heating values and specific gravities of LPG and gasoline, it can be shown that 1.36 LPG gallons have the same energy content as 1 gallon of gasoline. Based on this, we expect that the fuel economy for operation on LPG should be 73.53% of that for operation on gasoline, when both are expressed on the basis of actual gallons.

Table 2 reveals that, on average, the bi-fuel vehicles running on LPG only exhibited a fuel economy 75.76% that of the average for those running on gasoline only when both are expressed in actual gallons rather than equivalent gallons. Within the uncertainty of the data, this agrees with the theoretical value (73.53%). This result was expected because "The Texas Project" (Matthews et al., 1996; Chiu and Matthews, 1996; Wu et al., 1996, 1998a), showed that, on average, bi-fuel LPG vehicles had the same fuel economy on LPG as when tested on gasoline when both are expressed in miles per equivalent gallon of gasoline (mpegg). In other words, over a wide variety of environmental and vehicle operating conditions, LPG and gasoline yield the same fuel economy in mpegg. Equivalently, the fuel economy when operating on LPG is 73.53% of that for operation on gasoline, when both are expressed on the basis of actual gallons.

Table 2. Fuel Economy for Trucks Operating Exclusively on Either LPG or Gasoline over an Extended Period

	Bi-Fuel Vehicle Equipment Number	Number of ~ Points	Mean (miles per actual gallon)	Ratio of MPG(gas) to MPG (LPG)
LPG-only	03649G	11	9.62	1.34
gasoline-only		5	12.93	
LPG-only	03651G	2	9.67	1.25
gasoline-only		8	12.09	
LPG-only	03652G	7	11.32	1.12
gasoline-only		6	12.73	
LPG-only	05974F	5	9.51	1.41
gasoline-only		3	13.45	
LPG-only	05994F	12	9.91	1.31
gasoline-only		10	12.95	
LPG-only	05995F	5	8.00	1.50
gasoline-only		1	12.03	
LPG-only	05996F	15	9.22	1.29
gasoline-only		9	11.88	
Average ratio				1.32

Because of this agreement between the theoretical value and both previous and current experimental data, the combined (overall LPG and gasoline use) fuel economy for the bi-fuel vehicles was calculated using the equivalence:

$$1.36 \text{ LPG gallons} = 1.0 \text{ gasoline gallon} \quad (1)$$

Four methods for calculating the fuel economy from the recorded data are discussed in Appendix B. Appendix C summarizes the statistical analysis. As expected, the four different methods for calculating the fuel economy do not yield results that are statistically different at the 95% confidence level. Specifically, all yield a fuel economy for combined operation on both LPG and gasoline of ~12.7 mpegg. Furthermore, the fuel economy for the gasoline-only vehicles cannot be said (with at least 95% confidence) to be statistically different from that for the bi-fuel vehicles. This is much less than the EPA-rated highway and urban fuel economy of these vehicles, 18 miles/gallon and 14 miles/gallon, respectively, illustrating the importance of the duty cycle on the fuel economy. The results in Table 2 also illustrate the dependence of the fuel economy on the duty cycle: during gasoline-only operation one vehicle obtained 11.88 mpg; another had a fuel economy of 13.45 mpg (14% higher). This dependence of the fuel economy on the duty cycle is also evident for the bi-fuel vehicles. For example, in Appendix A, the vehicle with the worst combined fuel economy over the project period averaged 9.92 mpegg. Another that used LPG essentially as often averaged 13.87 mpegg (40% higher).

Because of the different energy contents of LPG and gasoline, the fuel economy in miles per actual gallon depends on the percent use of LPG. A vehicle that has a fuel economy of 12.7 mpegg will achieve 12.7 miles per actual gallon when operating exclusively on gasoline and 9.3 miles per actual gallon when operating exclusively on LPG. For bi-fuel vehicles, the relationship between miles per actual gallon and percent use of LPG is illustrated in Figure 3. Data extracted from the database records (Table A-2) for those vehicles achieving a combined fuel economy of 12.7 mpegg \pm 6% is also shown in Figure 3 for comparison. As expected, the agreement between the data and the theory is quite good.

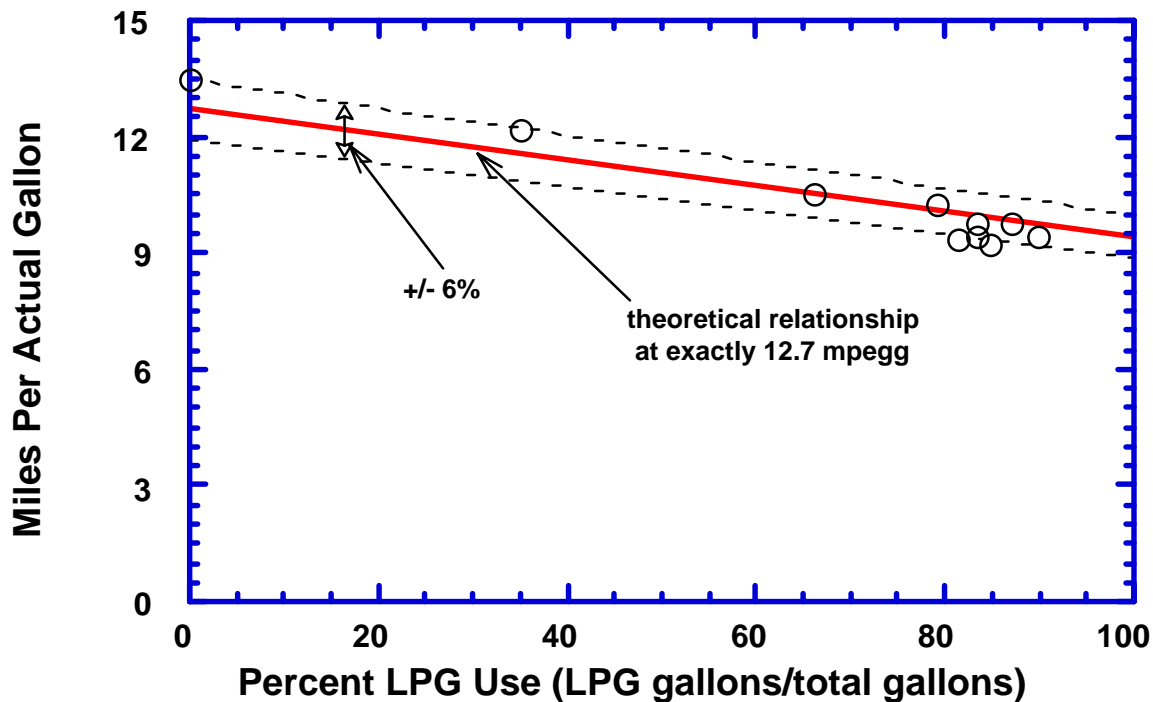


Figure 3. Fuel economy in miles per actual gallon as a function of percent LPG used for the vehicles that averaged 12.7 mpegg \pm 6%
(Circles on the plot represent selected fuel economy data.)

Percent Use of LPG

The same data sets used to determine the fuel economy were used to examine the percent use of LPG:

$$\%LPG = 100 * TPU / (TPU + TGU) \quad (2)$$

where TPU is the total gallons of LPG used over the period of the project (in actual LPG gallons) and TGU is the total gallons of gasoline, for each individual vehicle. Data from both the vehicle operation log forms and from the TxDOT database were used to calculate the percent use of LPG, and Appendix C summarizes the statistical results. As expected, the two data sets yield a value that cannot be said to be statistically different with at least 95% confidence. Specifically, the bi-fuel vehicles in the study fleet averaged ~78% use of LPG.

Fuel Operating Cost

The fuel operating cost depends on the fuel economy and the percent use of LPG, both of which were discussed above. Additionally, the fuel operating cost depends on the purchase price of the fuel. Fuel prices are discussed below, followed by results for the fuel operating cost.

The fuel price depends on the type of fleet. State-owned fleets do not pay federal taxes on gasoline, but private fleets do pay federal taxes (at the pump). In Texas, both private vehicles and state fleet vehicles pay a state tax on gasoline at the pump and both pay a state tax on LPG via an annual tax on AFVs. This annual tax is discussed in a later section.

A discount on LPG can be obtained via a large bulk purchase, and large private fleets and state fleets can realize this savings. The Corpus Christi district has not installed an on-site LPG refueling facility, but the Houston district does have an LPG refueling facility on site. However, TxDOT pays about the same as for off-site refueling because even for off-site purchases, TxDOT has a contract for LPG that is the sum of a fixed cost plus an increment for the fluctuating market price (and the market price changes weekly). In both the Houston and Corpus districts, fleets are fueled with gasoline both on and off site. The off-site contract for gasoline is similar to that for LPG (i.e., bulk purchase discount), except that the market price increment does not fluctuate as much. According to the Texas Railroad Commission, the average price of LPG available to the general public in absence of a bulk discount is typically \$0.81 per LPG gallon (\$1.10 per equivalent gallon). In comparison, the maximum that either of these two TxDOT districts paid for LPG during this project was approximately 70.6¢ per LPG gallon.

Figure 4 illustrates the monthly variations, resulting from the fluctuating market price, in the prices TxDOT paid for gasoline and LPG during this project. The contract that the Corpus district has with its LPG vendors results in a 12.23¢ per LPG gallon higher LPG price than paid in the Houston district. As discussed in Appendix C, the average price paid by TxDOT, for the duration of this project, was 79.79¢/gallon for gasoline, 61.75¢ per LPG gallon in the Corpus district, and 49.52¢ per LPG gallon in the Houston district. The 79.79¢/gallon average for gasoline reflects both the discount for bulk purchase and the fact that state agencies do not pay the federal tax on gasoline. Here, it should again be noted that the gasoline price includes state tax paid at the pump whereas the LPG price does not. Instead, the state "road tax" for LPG is paid via an annual tax on the alternative fuels.

The fuel operating cost (FOC) for each vehicle was determined using the equation:

$$\text{FOC } [\$/\text{mile}] = (\text{TPC} + \text{TGC}) / \text{TMD} \quad (3)$$

where TPC and TGC are the costs for the total gallons of LPG and gasoline consumed, respectively, and TMD is the total miles driven.

Appendix C presents the results from the statistical analyses of the data. As expected, the two sets of data for the bi-fuel vehicles in each district yield results that are not statistically different with at least 95% confidence. This is also true for the results from the two sets of data for the gasoline-only vehicles. Somewhat surprisingly, the statistical analyses discussed in Appendix C also indicate that the fuel operating cost is not statistically different, with at least 95% confidence, between the gasoline-only and bi-fuel vehicles. This results from several factors. First, the number of vehicles is small, especially for the gasoline-only vehicles, and this yields a significant uncertainty in the value of the true mean. Furthermore, the fuel operating cost is a function of the duty cycle, the percent use of LPG, and the relative prices of LPG and gasoline. These factors combine to produce very broad distributions in the data.

As noted above, although the fuel operating cost was calculated using Equation 3 solely from the total LPG and gasoline costs over the miles accumulated during the project, in fact it is a function of the fuel economy (duty cycle), percent use of LPG, and relative prices of LPG and gasoline. This dependence is demonstrated via the following equation:

$$\begin{aligned} \text{FOC } (\$/\text{mi}) = & \frac{\$/\text{LPG gallon}}{\text{FE}_{\text{LPG}}(\text{mi} / \text{LPG gal})} \cdot \frac{\% \text{LPG}}{100} \left(\frac{\text{LPG gals}}{\text{total gals}} \right) \\ & + \frac{\$/\text{gasoline gallon}}{\text{FE}_{\text{gas}}(\text{mi} / \text{gasoline gal})} \cdot \left\{ 1 - \frac{\% \text{LPG}}{100} \right\} \left(\frac{\text{gasoline gals}}{\text{total gals}} \right) \end{aligned} \quad (4)$$

where FE_{LPG} is the fuel economy while operating on LPG in miles per actual LPG gallon, FE_{gas} is the fuel economy while operating on gasoline, and $\%LPG/100$ is the LPG fraction of the total gallons of fuel consumed.

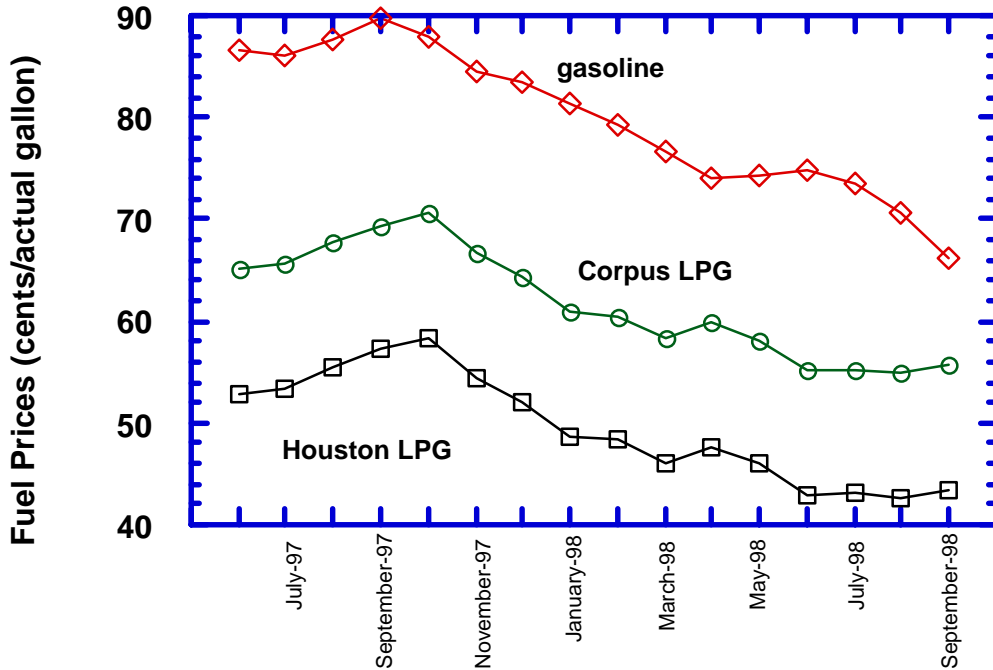


Figure 4. Monthly purchase prices of gasoline and LPG (Note: the price of LPG was higher in the Corpus district than in the Houston district.)

Equation 4 can be used to eliminate many of the variables that produce the broad distributions in the data. In turn, this allows comparison of the gasoline-only and bi-fuel vehicles without these complicating factors. As discussed previously, for this study fleet the fuel economy, on average, is 12.7 mpegg or 12.7 mpg for gasoline and $12.7/1.36 = 9.3$ miles per actual gallon of LPG. The other variables that can be fixed are the average costs of gasoline (79.79¢/gal) and LPG (61.75¢ per actual LPG gallon in the Corpus district; 49.52¢ per actual LPG gallon in the Houston district). Therefore, for a vehicle that averages 12.7 mpegg in the Corpus district, Equation 4 becomes:

$$FOC_{avg}^{Corpus} (\$/mi) = \frac{\$0.6175 / \text{LPG gal}}{9.3 \text{ mi / LPG gal}} \cdot \frac{\%LPG}{100} + \frac{\$0.7979 / \text{gasol. gal}}{12.7 \text{ mi / gasol. gal}} \cdot \left\{ 1 - \frac{\%LPG}{100} \right\} \quad (5a)$$

and for this vehicle in the Houston district:

$$FOC_{avg}^{Houston} (\$/mi) = \frac{\$0.4952 / \text{LPG gal}}{9.3 \text{ mi / LPG gal}} \cdot \frac{\%LPG}{100} + \frac{\$0.7979 / \text{gasol. gal}}{12.7 \text{ mi / gasol. gal}} \cdot \left\{ 1 - \frac{\%LPG}{100} \right\} \quad (5b)$$

The fuel operating cost is shown as a function of percent LPG usage in Figure 5 for the TxDOT vehicles that averaged $12.7 \text{ mpegg} \pm 6\%$ (from the database records). Two aspects of this graph are of note. The first is that Equation 5 predicts the data within ~0.3 cents/mile, as expected because there are no assumptions in this equation. The second, and most obvious, is that the fuel operating cost increases

with increasing use of LPG for the Corpus district but decreases with increasing LPG usage for the Houston district. This is because the Corpus district of TxDOT pays more for LPG than for gasoline on an energy content basis ($61.75 \times 1.36 = 84\text{¢}$ per energy equivalent gallon for LPG compared to ~ 80 cents/gallon for gasoline); the Houston district pays less for LPG than gasoline ($49.52 \times 1.36 = 67\text{¢}$ per energy equivalent gallon for LPG).

The strong effect that the difference in fuel purchase price (the margin or spread) has on the economics of AFVs has been previously reported (Dardalis et al., 1998). The margin between LPG and gasoline for this period of TxDOT operation was in the wrong direction for the Corpus district, with gasoline being the less expensive fuel. The break-even point, when the fuel operating cost is independent of the use of LPG, occurs when the cost per actual LPG gallon equals the cost per gallon of gasoline divided by 1.36. For gasoline at 79.79¢ per gallon, it will cost more to operate on LPG if the cost of LPG is more than 58.67¢ per LPG gallon (as demonstrated in the Corpus district). On the other hand, it will cost less to operate on LPG than gasoline if the LPG can be purchased at less than 58.67¢ per LPG gallon (as was the case for the Houston district). In comparison, the City of San Antonio makes large bulk purchases of LPG to obtain it at $\sim \$0.30$ per actual gallon (41¢ cents per equivalent gallon). For San Antonio's fleet, the slope in Figure 5 would be even more favorable to using LPG than for TxDOT's Houston district.

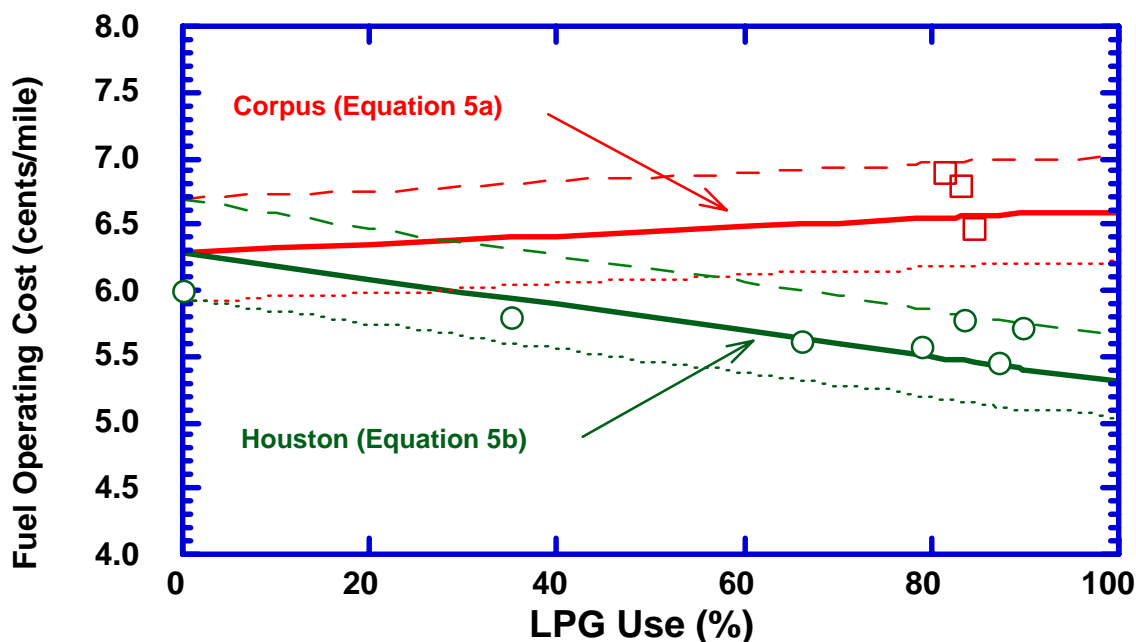


Figure 5. Fuel operating cost versus percent LPG usage. Data are shown for vehicles that averaged $12.7 \text{ mpegg} \pm 6\%$. Notes: Houston = circles, Corpus = squares; solid lines are theoretical relationships for vehicles that achieve precisely 12.7 mpegg ; dashed lines are for vehicles with 6% lower fuel economy (11.94 mpegg) via Equations 5a and 5b; and dotted lines are for vehicles with 6% higher fuel economy (13.46 mpegg) via Equations 5a and 5b.

Texas' Annual Tax on Alternative Fuels

As noted above, fleets pay the state tax on LPG indirectly by an annual tax, which depends on the annual mileage accumulation rate and the vehicle weight. For the F150 pickups that are the subject of this study, the annual tax is \$42 for < 5000 miles, \$84 for 5000–9999 miles, \$126 for 10,000–14,999 miles, and \$168 for more than 15,000 miles per year. On a per mile basis, this tax is illustrated in Figure 6. The overall TxDOT fleet averages about 15,000 miles per year, at the break point between 0.8 and 1.2 cents per mile. The TxDOT vehicles in the study fleet averaged 17,153 miles per year. If each of the study vehicles averaged 17,153 miles per year, the cost per vehicle for this annual tax would be 0.979 cents per mile. However, because the tax is not a linear function of miles per year (as illustrated in Figure 6), vehicles that accumulate mileage slowly pay a much higher tax in cents per mile. For this reason, the average cost of this annual tax for the study fleet was 1.326 cents per mile. This annual tax on LPG adds to the fuel operating cost for the bi-fuel vehicles independent of whether LPG is used exclusively or not at all.

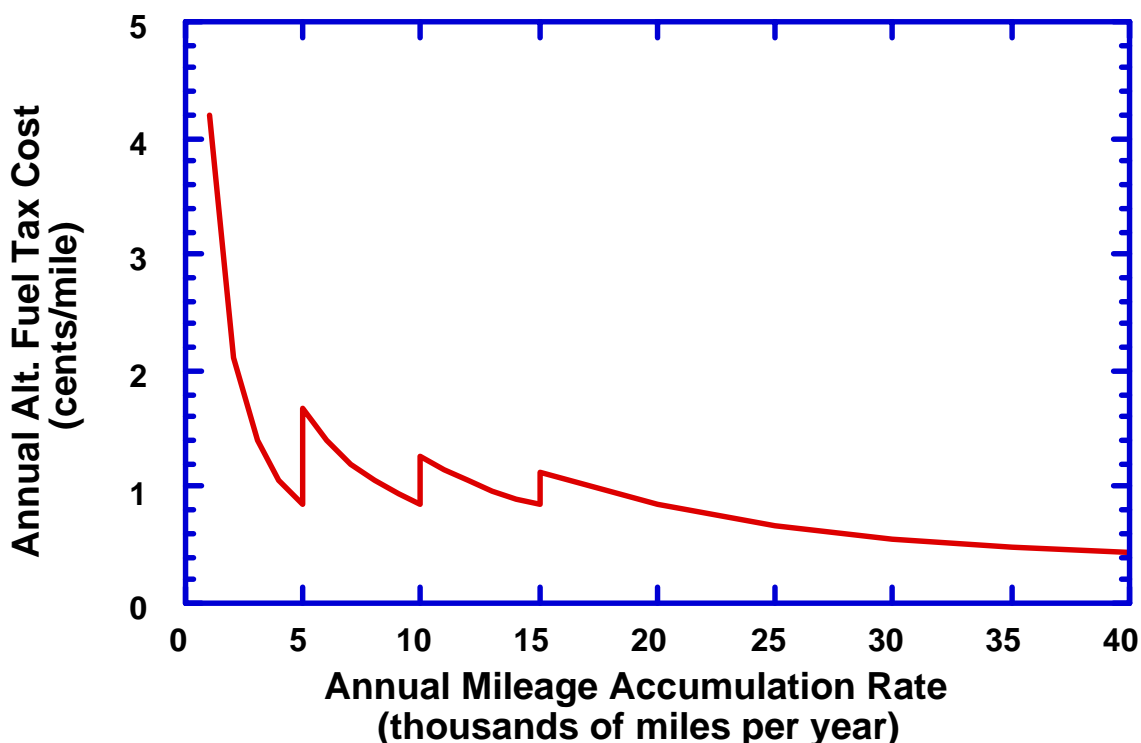


Figure 6. Texas' annual alternative fuel tax, expressed on a per-mile basis

Maintenance and Reliability

Each month, we visited the Houston and Corpus district sites and their affiliated Ford dealerships (which perform warranty repairs and non-warranty repairs) to collect vehicle maintenance records. These records were used to examine scheduled maintenance, unscheduled maintenance (repairs), and reliability.

For all of the TxDOT vehicles, scheduled maintenance was normally performed by mileage increment, with the exception of oil changes that occurred about every 3 months or 3,000 miles, whichever occurred earlier. Similarly, the number of repairs, and therefore the repair cost, is also expected to be higher for vehicles that accumulated more miles. In other words, the maintenance per vehicle depends on the

mileage accumulated by that vehicle. For the vehicles in this project, the miles accumulated during the project period varied from a low of 5,676 miles to a high of 56,160 miles. Therefore, the results were analyzed on a cost-per-mile basis.

Appendix D presents the detailed results. Scheduled maintenance, unscheduled maintenance, and reliability are discussed in the following sections.

From the data for each vehicle, as divided into bi-fuel and gasoline-only subgroups, we analyzed the following:

Scheduled Maintenance

This category included:

- Labor cost for each vehicle in cents/mile
- Parts cost for each vehicle in cents/mile
- Other costs for each vehicle (e.g., used oil disposal) in cents/mile
- Total scheduled maintenance cost for each vehicle in cents/mile.

Scheduled maintenance includes oil changes, oil and air filter replacements, and chassis lubrication. TxDOT performs some of the scheduled maintenance; some is contracted to local vendors. Oil changes are an example of scheduled maintenance that is performed sometimes by TxDOT and sometimes by vendors. Some of the vendors charge a fixed total cost rather than itemizing by parts and labor. In this report, for oil changes performed by such vendors, we apportioned the costs according to the oil change records from the vendors that did itemize.

Additionally, the Houston district uses conventional replacement oil filters whereas the Corpus district uses permanent oil filters that are cleaned rather than replaced. For this reason, the scheduled maintenance data were sorted into bins representing the Corpus and Houston district vehicles separately.

Appendix E presents the summary statistics for scheduled maintenance. Table 3 shows the means and standard deviations (the uncertainty is relatively large, as noted from the standard deviations). Because all the TxDOT vehicles perform scheduled maintenance on the suggested "harsh service" rate of, nominally, every 3 months or 3,000 miles, the scheduled maintenance costs are expected to be the same for the bi-fuel and gasoline-only vehicles. As expected, the mean scheduled maintenance cost per mile for the gasoline-only vehicles is not statistically different (with at least 95% confidence) from that for the bi-fuel vehicles in the Houston district. Specifically, the mean total (parts plus labor plus "other") cost for scheduled maintenance is ~ 65 cents/mile for the gasoline-only vehicles and for the bi-fuel vehicles in the Houston district. However, because permanent oil filters are used in the Corpus district, the cost of parts for scheduled maintenance is ~38% lower, but the labor cost is 132% higher for scheduled maintenance in the Corpus district than the Houston district. In other words, the use of permanent oil filters in the Corpus district increases the total cost for scheduled maintenance from ~65 cents/mile to 82 cents/mile.

Table 3. Mean Costs for Scheduled Maintenance (\$/mile)

	Bi-Fuel		Gasoline-Only
	Corpus	Houston	All
Number of Vehicles	16	15	4
Parts Costs	0.20	0.32	0.33
Labor Costs	0.58	0.25	0.29
Other Costs	0.04	0.06	0.05
Total Costs	0.82	0.63	0.67
Standard Deviation of Total Costs	0.21	0.13	0.16

Unscheduled Maintenance

This category comprised:

- Unscheduled maintenance operating cost for each vehicle in cents/mile
- LPG-related maintenance operating cost for each vehicle in cents/mile
- Non-LPG-related maintenance operating cost for each vehicle in cents/mile
- Total maintenance operating cost for each vehicle in cents/mile.

Projected Repair Costs after the Warranty Period

The warranty period for these vehicles is 3 years or 36,000 miles, whichever comes first. All but three of the study vehicles were under warranty throughout the project. Therefore, virtually all the repairs were performed at no cost to TxDOT. However, TxDOT generally keeps its vehicles until well after 36,000 miles. Therefore, it was of interest to try to project the repair costs that might be expected after the expiration of the warranty. This section covers the method of projecting these costs, and the results of this analysis.

In general, repairs were performed at the local Ford dealerships. Because all these vehicles were under warranty until near the end of the project, the dealer's repair invoices usually only listed the parts itemization (without associated parts costs) and repair hours. The parts costs were obtained by presenting the parts lists to the dealership's parts counter and acquiring the associated list of costs. The dealer charges the vehicle manufacturer a higher labor rate for warranty repairs than it charges regular customers. Thus, the labor cost was calculated for each repair as the product of the repair hours and the customary labor charge (for individual customers).

As illustrated in Figure 7, the total number of repairs was highly variable: one vehicle required eight repairs in less than 20,000 miles; others did not require any repairs after traveling twice as far. One goal of this study was to examine the additional cost for bi-fuel vehicles relative to gasoline-only vehicles, but the statistical basis for the gasoline-only vehicles is small. For this reason, we also examined the portion of the unscheduled maintenance that resulted from the LPG system. All of the LPG-related maintenance fell within three categories: propane fill valve leaking, propane fuel/switch malfunction, and propane indicator light malfunction. Examples of the non-LPG-related repairs on the bi-fuel vehicles include:

- Flat tire repair
- Starter relay replacement
- Windshield replacement
- Power steering pump replacement

- Fan belt tensioner replacement
- Front end alignment.

These are examples of repairs that probably would have been required even if these vehicles had not been converted to LPG, as they have nothing to do with the fuel system. For the bi-fuel study vehicles, all required fuel system repairs were LPG-related. This study indicates that the gasoline fueling systems are more reliable than the LPG systems, although vehicles in both categories require repair of systems that are totally unrelated to the fuel. One purpose of this analysis was to project the additional repair costs related to these vehicles having been converted to bi-fuel operation, and incurred after the warranty period.

Three of the four gasoline-only vehicles had repairs, but one of these three had only a flat tire repair. In contrast, 28 of the 31 bi-fuel vehicles required repair. An over-simplified analysis, which overlooks the very small sample size of the gasoline-only vehicle pool, might yield the conclusion that only 15 of every 30 gasoline-only F150s would require repair over the project period. The addition of an LPG system (the bi-fuel vehicles) would appear to result in almost 90% of these vehicles needing repairs during this time span. However, only 13 of the 31 bi-fuel vehicles required LPG-related repairs. This, again, emphasizes the problem of extrapolating from a small data pool (the four gasoline-only vehicles) for phenomena that are as irregular as repairs.

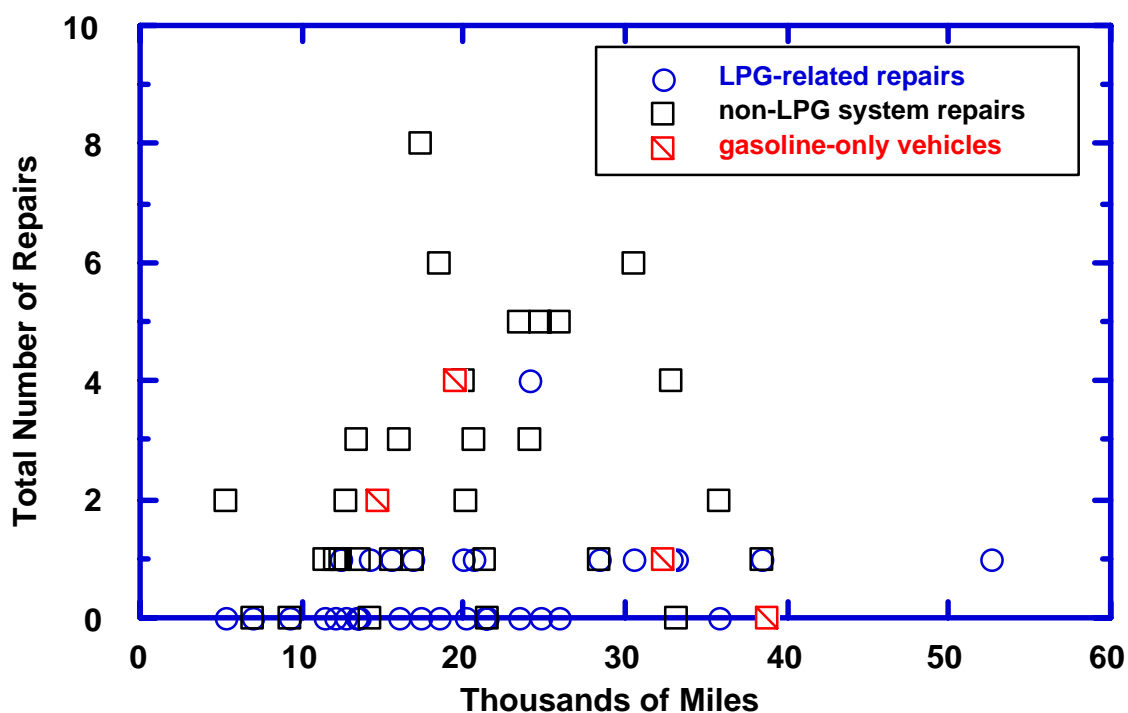


Figure 7. Total number of repairs versus total miles accumulated over the project period. Each vehicle, except the gasoline-only vehicles, has two data points at its final mileage at the end of the project: a circle for the number of LPG system repairs and a square for the number of non-LPG-related repairs.

The limitations of the small gasoline-only data set can be addressed by examining the difference between the LPG-related maintenance and the total unscheduled maintenance; this is the portion of unscheduled

maintenance that is expected to have occurred even if the vehicle had not been converted to bi-fuel operation. Appendix E presents the summary statistics for the unscheduled maintenance (repairs).

The projected non-LPG-related repair cost for the bi-fuel vehicles is 1.98 cents/mile. This is based on a much larger sample size than is available for the gasoline-only vehicles and includes only repairs that are not related to the LPG system. Therefore, it is assumed that this repair cost of approximately 1.98 cents/mile, after the warranty period, is also applicable to the gasoline-only vehicles.

It is expected that the repair costs for the bi-fuel vehicles will be higher simply because there is additional hardware on these vehicles. On average for the bi-fuel vehicles in this study, the additional hardware for the LPG system adds a projected 0.77 cents/mile to the repair cost of the bi-fuel vehicles. That is, the bi-fuel vehicles are expected to have a repair cost (after the warranty period) that is 39% higher than that estimated for gasoline-only operation.

Reliability

We used the number of unscheduled maintenance occurrences per 5,000 miles to evaluate the reliability of the vehicles being studied. Figure 8 presents the results for each of the vehicles and Appendix E provides a statistical summary. The corresponding data are available in Appendix D.

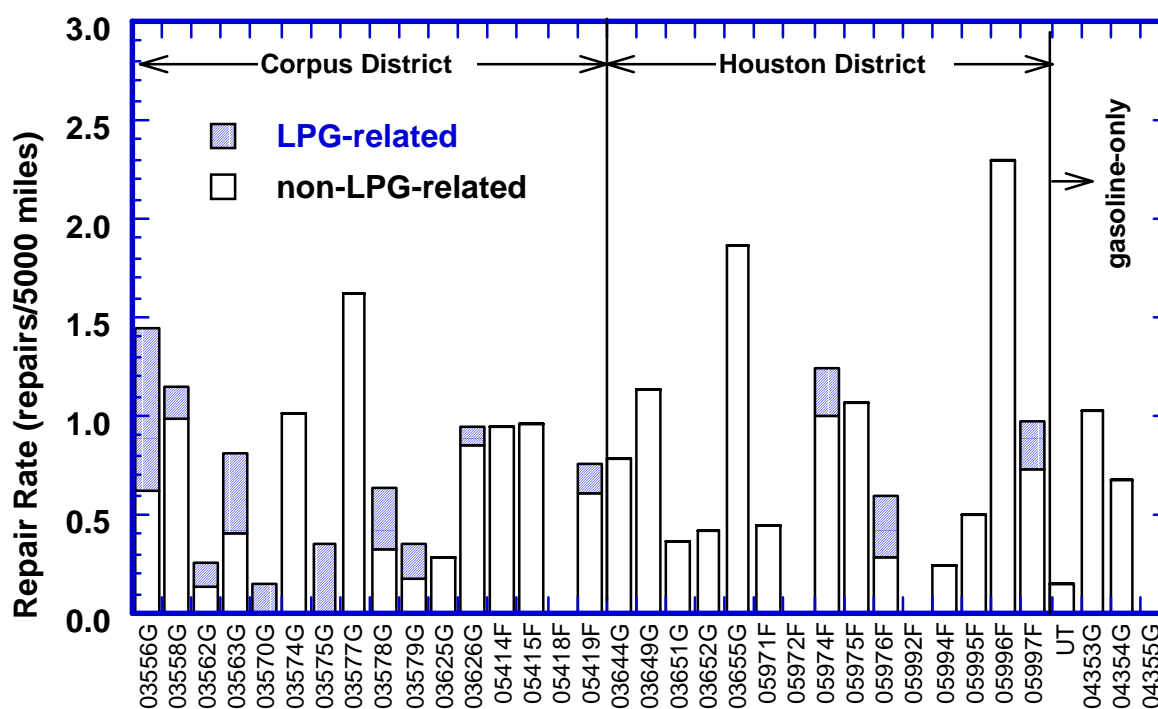


Figure 8. Comparisons of the repair rates for the study vehicles

As discussed in Section E.3 of Appendix E, the repair rates for the gasoline-only vehicles are not statistically different (with at least 95% confidence) from the non-LPG system repair rates for the bi-fuel vehicles. It is estimated that the baseline repair rate (that expected whether or not the vehicle has a LPG system) is 6.5 repairs per 50,000 miles. On average, the LPG system requires about one repair every 50,000 miles compared to about 7 repairs every 50,000 miles for the remaining systems. The present finding of 1.1 additional repairs every 50,000 miles agrees surprisingly well with that from a previous

study (Dardalis et al., 1998), which found 1.25 repairs every 50,000 miles but examined only five bi-fuel LPG vehicles.

As expected, gasoline-only vehicles are more reliable than bi-fuel vehicles because bi-fuel vehicles have additional components. However, the reliability of the LPG system is, on average, quite good. On average, about 15% of unscheduled maintenance is related to the LPG system.

Summary of Operating Costs for Identical Gasoline and Bi-Fuel Vehicles

The uncertainty in the true means is very high for many of the cost categories of interest to this study (see discussions and analyses in Appendix C and E). This results from the small sample size, especially for the gasoline-only vehicles, and from the fact that many of the cost factors are functions of parameters that could not be held constant during the study: the duty cycle (in-use fuel economy), the miles accumulated annually, the percent use of LPG, and the relative costs of LPG and gasoline. However, the results of this study do allow the costs of identical gasoline-only and bi-fuel vehicles to be calculated.

To perform the calculations to allow comparison of the operating costs of bi-fuel vehicles with those of gasoline-only vehicles, those factors that could not be held constant for the study vehicles must be specified. These specifications are enumerated below.

On average, the vehicles in the study fleet traveled 17,153 miles per year. The State of Texas would assess an annual alternative fuels tax of \$168 per year for bi-fuel vehicles that accumulate more than 15,000 miles per year. Therefore, the cost for this annual tax would be 0.979 cents/mile for a bi-fuel vehicle that accumulates 17,153 miles per year. This cost replaces the state road tax on gasoline that is paid at the pump.

On average, the fuel economy of the study vehicles was ~12.7 miles per equivalent gallon of gasoline. Because of the differences in energy densities between gasoline and LPG, a bi-fuel vehicle that achieves 12.7 mpegg will get 12.7 mpg when operating on gasoline and 9.3 miles per actual LPG gallon when operating on LPG. On average, for the bi-fuel vehicles in this study, LPG accounted for ~78% of the total gallons of fuel used (gasoline plus LPG). A bi-fuel vehicle that has a fuel economy of 12.7 mpegg and uses LPG 78% of the time will have a fuel economy of 10.08 miles per actual gallon of LPG plus gasoline.

The fuel operating cost also depends on the difference between the prices of gasoline and LPG (the spread or margin). This margin determines whether or not there will be a fuel operating cost benefit or penalty for operation on LPG, and the size of this benefit or penalty. For the purpose of this analysis, the margin is taken from the average fuel prices during this study: 79.79 cents/gallon for gasoline, 61.75 cents/actual LPG gallon in the Corpus district, and 49.52 cents/actual LPG gallon in the Houston district. For the assumed 78% use of LPG and 12.7 mpegg, these price differences correspond to fuel operating costs of 6.28 cents/mile, 6.51 cents/mile, and 5.53 cents/mile, respectively.

Because TxDOT performs routine scheduled maintenance on a fixed (fuel independent) schedule, the scheduled maintenance operating cost was not statistically different for the gasoline-only vehicles and the bi-fuel vehicles in the Houston District (at ~65 cents/mile). Because of the high labor cost for the reusable oil filters in the Corpus District, their cost for routine scheduled maintenance was 82 cents/mile. Although the additional maintenance cost of the reusable oil filters is not related to the fact that these are bi-fuel vehicles, this cost is accounted for in this analysis for the sake of completeness.

Three of the 35 study vehicles came out of warranty near the end of the project. Therefore, there were essentially no repair (unscheduled maintenance) costs for the study fleet. However, because TxDOT keeps vehicles for much longer than the warranty period, projections were made for the repair costs after expiration of the warranty. As discussed in Section 3.B, it is projected that the base repair cost is 1.98 cents/mile independent of whether or not it is a bi-fuel vehicle, but that the LPG system adds an additional 0.77 cents/mile to the repair cost after the warranty period.

Table 4 summarizes the costs calculated for identical bi-fuel and gasoline-only vehicles that travel 17,153 miles per year, have a fuel economy of 12.7 mpg, and conform to the other specifications enumerated above. Before the warranty expires, bi-fuel vehicles in the Houston district have a cost of 0.23 cents/mile more than identical gasoline vehicles for the cost categories considered in this study. This relatively small penalty could be diminished to zero, or become a cost benefit, with more miles accumulated per year (which diminishes the annual tax on a per-mile basis). This penalty could also be diminished by a lower rate for the annual tax on the alternative fuels in Texas, or via a somewhat lower price for LPG. For the Corpus district, during the warranty period, the bi-fuel vehicles cost 1.38 cents/mile more to operate than gasoline-only vehicles that do not use reusable oil filters. Of this additional 1.38 cents/mile, 0.17 cents/mile is due to the higher scheduled maintenance cost for the reusable oil filters with the remainder resulting from the relatively high cost of LPG in the Corpus district (the Corpus district pays more per energy equivalent gallon for LPG than it does for gasoline). In other

Table 4. Summary of Costs for Bi-Fuel and Gasoline-Only Vehicles (cents/mile)

	gasoline-only	Corpus bi-fuel	Houston bi-fuel
% LPG	0	78	78
fuel cost per mile	6.28	6.51	5.53
annual tax (per mile)	0	0.98	0.98
scheduled maint. cost per mile	0.65	0.82	0.65
projected repair cost per mile	1.98	1.98	1.98
projected LPG-related repairs	0	0.77	0.77
Total during warranty	6.93	8.31	7.16
Projected total after warranty	8.91	11.06	9.91

words, during the warranty period, the bi-fuel vehicle in Houston costs 3.2% more per mile to operate and the bi-fuel vehicle in Corpus costs 19.9% more per mile than the comparable gasoline-only vehicle for the cost factors considered in this study. For the Corpus district, the cost of the bi-fuel vehicle would be 17.5% higher if both had replacement-type oil filters.

After the warranty expires, it is projected that the bi-fuel vehicles will cost an additional 0.77 cents/mile (on top of the costs during the warranty period plus a baseline repair cost of 1.98 cents/mile) because of the repair costs for the LPG systems. After the warranty expires, then, the operating costs for the bi-fuel vehicle will be 11.2% higher than for the gasoline-only vehicle in the Houston district. For the Corpus district, the cost of the bi-fuel vehicle will be 24.1% higher than for the gasoline-only vehicle (this would be an additional cost of 22.2% if both had replacement-type oil filters).

Summary and Conclusions

Thirty-one bi-fuel pickups were studied over a 2-year period, during which detailed operational and maintenance data and cost were acquired for 18 months. Four nominally identical gasoline-only vehicles

were leased for comparison. All but one of these vehicles was used for normal daily service in the largest fleet in Texas, which is operated by TxDOT.

Two of the operating costs for bi-fuel vehicles were examined: fuel and maintenance. The maintenance items were categorized into scheduled maintenance and repairs; the latter was further divided into repairs to the LPG system and repairs that were not related to the LPG system. Essentially all the repairs were covered under warranty. However, TxDOT keeps its vehicles until well after the warranty expires. Therefore, details regarding the repairs during the warranty period were used to project repair costs following the warranty's expiration.

On average, the vehicles in the study fleet traveled about 17,000 miles per year (near the average for TxDOT's overall fleet). For the bi-fuel vehicles, LPG accounted for ~78% of the total gallons of fuel used (gasoline plus LPG).

On average, the fuel economy of the study vehicles was ~12.7 miles per equivalent gallon of gasoline. This is much lower than the rated fuel economy of this vehicle, illustrating the importance of duty cycle on fuel economy. Because of the differences in energy densities between gasoline and LPG, a bi-fuel vehicle that achieves 12.7 mpegg will get 12.7 mpg when operating on gasoline and 9.3 miles per actual LPG gallon when operating on LPG. If this bi-fuel vehicle averages 78% use of LPG, as was the case for the study fleet, it will have a fuel economy of 10.08 miles per actual gallon of LPG plus gasoline. Texas' annual tax on alternative fuels was also quantified on a cost-per-mile basis.

Because TxDOT performs routine scheduled maintenance on a fixed (fuel-independent) schedule, the scheduled maintenance operating cost (cents/mile) was not statistically different for the bi-fuel and gasoline-only vehicles. However, in the Corpus district, the bi-fuel vehicles followed the same schedule but used permanent oil filters on these vehicles, which resulted in higher costs for scheduled maintenance resulting from the increased labor cost to clean the filters. The additional hardware (for the LPG systems) on the bi-fuel vehicles resulted, as expected, in additional repairs; on average there were 1.1 LPG-system repairs per 50,000 miles. Overall, about 15% of the repairs resulted from the LPG system.

References

- Chiu, J., and R.D. Matthews, 1996, "The Texas Project: Part 2—Investigation of Calibrations of Aftermarket CNG and LPG Conversion Technologies," SAE Paper 962099, also in: *Journal of Fuels and Lubricants* 105:2206, 1996.
- Dardalis, D., R.D. Matthews, D. Lewis, and K. Davis, 1998, "The Texas Project Part 5—Economic Analysis: CNG and LPG Conversions of Light-Duty Vehicle Fleets," SAE Paper 982447; also in: *Alternative Fuels*, SAE Special Publication SP-1391, pp. 43-56.
- Herridge, J.T., and J.E. Lambert, 1995, "Fleet Economic Analysis—CleanFleet Alternative Fuels Project," SAE Paper 950395.
- Hochhauser, A.M., J.D. Benson, V.R. Burns, R.A. Gorse, Jr., W.J. Koehl, L.J. Painter, R.M. Reuter, and J.A. Rutherford, 1993, "Fuel Composition Effects on Automotive Fuel Economy—The Auto/Oil Air Quality Improvement Research Program," SAE Paper 930138; also in: *Auto/Oil Air Quality Improvement Research Program - Volume II*, SAE Special Publication SP-1000.
- Matthews, R.D., J. Chiu, J. Zheng, D.-Y. Wu, D. Dardalis, K. Shen, C. Roberts, M.J. Hall, J.L. Ellzey, C. Mock, R.B. Wicker, and S. Jaeger, 1996, "The Texas Project: Part 1—Emissions and Fuel Economy of Aftermarket CNG and LPG Conversions of Light-Duty Vehicles," SAE Paper 962098, also in: *Journal of Fuels and Lubricants*, 105:2186, 1996.

Wang, Q., D. Sperling, and J. Olmstead, 1993, "Emission Control Cost Effectiveness of Alternative-Fuel Vehicles," SAE Paper 931841.

Wu, D.-Y., R.D. Matthews, J. Zheng, K. Shen, J.P. Chiu, and C. Mock, 1996, "The Texas Project Part 3—Off-Cycle Emissions of Light-Duty Vehicles Operating on CNG, LPG, Federal Phase 1 Reformulated Gasoline, and/or Low Sulfur Certification Gasoline," SAE Paper 962100, also in: *Topics of Alternative Fuels and Their Emissions*, SAE Special Publication SP-1208, 1996.

Wu, D.-Y., R.D. Matthews, E. Popova, and C. Mock, 1998a, "The Texas Project Part 4—Final Results: Emissions and Fuel Economy of CNG and LPG Conversions of Light-Duty Vehicles," SAE Paper 982446; also in: *Alternative Fuels*, SAE Special Publication SP-1391, pp. 21-42.

Wu, D.-Y., D. Dardalis, R.D. Matthews, M.J. Hall, and J.L. Ellzey, 1998b, *The Texas Project: Conversions of Light-Duty Vehicles to CNG and LPG - Final Report*, submitted to the National Renewable Energy Laboratory.

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Appendix A
Monthly Data Regarding Fuel Use
(from log forms)

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

June-97											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel	1001.00	0.00	156.60	0.00	101.99	115.15	101.99	6.39	8.69	10.19
03558G	bi-fuel	2581.00	0.00	227.00	0.00	147.85	166.91	147.85	11.37	15.46	5.73
03562G	bi-fuel	2011.00	52.40	169.30	45.33	110.27	176.89	155.59	9.07	11.37	7.74
03563G	bi-fuel	715.00	11.00	0.00	9.52	0.00	11.00	9.52	65.00	65.00	1.33
03570G	bi-fuel	517.00	0.00	82.00	0.00	53.41	60.29	53.41	6.30	8.57	10.33
03574G	bi-fuel	716.00	70.00	0.00	60.55	0.00	70.00	60.55	10.23	10.23	8.46
03575G	bi-fuel	535.00	0.00	73.90	0.00	48.13	54.34	48.13	7.24	9.85	9.00
03577G	bi-fuel	1255.00	17.00	40.00	14.71	26.05	46.41	40.76	22.02	27.04	3.25
03578G	bi-fuel										
03579G	bi-fuel	2655.00	0.00	208.60	0.00	135.86	153.38	135.86	12.73	17.31	5.12
03625G	bi-fuel	1428.00	14.00	126.70	12.11	82.52	107.16	94.63	10.15	13.33	6.63
03626G	bi-fuel	2783.00	0.00	284.00	0.00	184.97	208.82	184.97	9.80	13.33	6.65
04355G	gasoline	2325.00	135.70		117.38		135.70	117.38	17.13	17.13	5.05
05414F	bi-fuel	645.00	11.50	68.00	9.95	44.29	61.50	54.24	8.11	10.49	8.41
05415F	bi-fuel	1038.00	0.00	119.00	0.00	77.50	87.50	77.50	8.72	11.86	7.47
05418F	bi-fuel		9.00	35.70	7.79	23.25	35.25	31.04			
05419F	bi-fuel	986.00		80.00	0.00	52.10	58.82	52.10	12.33	16.76	5.28
03644G	bi-fuel	1052.00	24.30	109.40	21.02	57.87	104.74	78.89	7.87	10.04	7.50
03649G	bi-fuel	983.00	6.00	102.30	5.19	54.12	81.22	59.31	9.08	12.10	6.03
03651G	bi-fuel	782.00	13.00	83.00	11.25	43.91	74.03	55.15	8.15	10.56	7.05
03652G	bi-fuel	1016.00	11.00	108.00	9.52	57.13	90.41	66.65	8.54	11.24	6.56
03655G	bi-fuel	563.00	11.50	38.90	9.95	20.58	40.10	30.53	11.17	14.04	5.42
04353G	gasoline	1401.00	105.90		91.60		105.90	91.60	13.23	13.23	6.54
04354G	gasoline	951.00	69.80		60.38		69.80	60.38	13.62	13.62	6.35
05971F	bi-fuel	169.00	0.00	41.00	0.00	21.69	30.15	21.69	4.12	5.61	12.83
05972F	bi-fuel	479.00	10.40	20.40	9.00	10.79	25.40	19.79	15.55	18.86	4.13
05974F	bi-fuel	1061.00	25.00	98.00	21.63	51.84	97.06	73.47	8.63	10.93	6.92
05975F	bi-fuel	1528.00	0.00	120.00	0.00	63.48	88.24	63.48	12.73	17.32	4.15
05976F	bi-fuel	609.00	0.00	21.00	0.00	11.11	15.44	11.11	29.00	39.44	1.82
05992F	bi-fuel	1102.00	11.00	78.90	9.52	41.74	69.01	51.25	12.26	15.97	4.65
05994F	bi-fuel	1096.00	14.00	156.30	12.11	82.68	128.93	94.79	6.44	8.50	8.65
05995F	bi-fuel	1492.00	11.00	163.00	9.52	86.23	130.85	95.74	8.57	11.40	6.42
05996F	bi-fuel	615.00	10.00	69.00	8.65	36.50	60.74	45.15	7.78	10.13	7.34
05997F	bi-fuel	1764.00	23.10	171.60	19.98	90.78	149.28	110.76	9.06	11.82	6.28
UT	gasoline	112.00	15.80		13.67		15.80	13.67	7.09	7.09	12.20

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

July-97											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel	1373.00	17.00	121.00	14.64	79.34	105.97	93.98	9.95	12.96	6.84
03558G	bi-fuel	2716.00	0.00	295.80	0.00	193.96	217.50	193.96	9.18	12.49	7.14
03562G	bi-fuel	2999.00	56.40	192.40	48.55	126.16	197.87	174.71	12.05	15.16	5.83
03563G	bi-fuel	378.00	14.00	25.00	12.05	16.39	32.38	28.45	9.69	11.67	7.53
03570G	bi-fuel	2046.00	64.00	207.20	55.10	135.86	216.35	190.96	7.54	9.46	9.33
03574G	bi-fuel	2481.00	189.30	0.00	162.97	0.00	189.30	162.97	13.11	13.11	6.57
03575G	bi-fuel	307.00	11.00	0.00	9.47	0.00	11.00	9.47	27.91	27.91	3.08
03577G	bi-fuel	2199.00	70.00	167.00	60.26	109.50	192.79	169.76	9.28	11.41	7.72
03578G	bi-fuel										
03579G	bi-fuel	1834.00	0.00	184.40	0.00	120.91	135.59	120.91	9.95	13.53	6.59
03625G	bi-fuel										
03626G	bi-fuel	2653.00	0.00	219.00	0.00	143.60	161.03	143.60	12.11	16.48	5.41
04355G	gasoline	2946.00	199.50		171.75		199.50	171.75	14.77	14.77	5.83
05414F	bi-fuel	1546.00	45.50	69.80	39.17	45.77	96.82	84.94	13.41	15.97	5.49
05415F	bi-fuel										
05418F	bi-fuel	1176.00	8.00	94.00	6.89	61.64	77.12	68.52	11.53	15.25	5.83
05419F	bi-fuel	2966.00	19.00	159.80	16.36	104.78	136.50	121.14	16.59	21.73	4.08
03644G	bi-fuel	913.00	26.30	68.90	22.64	36.75	76.96	59.39	9.59	11.86	6.51
03649G	bi-fuel	1008.00	4.00	105.80	3.44	56.43	81.79	59.88	9.18	12.32	5.94
03651G	bi-fuel	1302.00	26.00	139.90	22.38	74.62	128.87	97.01	7.85	10.10	7.45
03652G	bi-fuel	1264.00	0.00	120.00	0.00	64.01	88.24	64.01	10.53	14.33	5.06
03655G	bi-fuel	345.00	0.00	13.50	0.00	7.20	9.93	7.20	25.56	34.76	2.09
04353G	gasoline	1383.00	101.90		87.73		101.90	87.73	13.57	13.57	6.34
04354G	gasoline	1049.00	88.00		75.76		88.00	75.76	11.92	11.92	7.22
05971F	bi-fuel	1046.00	24.00	118.10	20.66	62.99	110.84	83.66	7.36	9.44	8.00
05972F	bi-fuel	558.00	15.40	20.00	13.26	10.67	30.11	23.93	15.76	18.53	4.29
05974F	bi-fuel	1386.00	13.00	131.00	11.19	69.88	109.32	81.07	9.63	12.68	5.85
05975F	bi-fuel	1554.00	15.00	199.00	12.91	106.15	161.32	119.06	7.26	9.63	7.66
05976F	bi-fuel	1634.00	28.20	146.00	24.28	77.88	135.55	102.15	9.38	12.05	6.25
05992F	bi-fuel	1879.00	36.00	219.20	30.99	116.92	197.18	147.91	7.36	9.53	7.87
05994F	bi-fuel	1143.00	0.00	119.20	0.00	63.58	87.65	63.58	9.59	13.04	5.56
05995F	bi-fuel	1368.00	0.00	135.40	0.00	72.22	99.56	72.22	10.10	13.74	5.28
05996F	bi-fuel	961.00	0.00	125.00	0.00	66.68	91.91	66.68	7.69	10.46	6.94
05997F	bi-fuel	2405.00	3.20	145.30	2.75	77.50	110.04	80.26	16.20	21.86	3.34
UT	gasoline	931.00	61.80		53.20		61.80	53.20	15.06	15.06	5.71

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

August-97											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel	768.00	49.70	40.00	43.56	27.06	79.11	70.63	8.56	9.71	9.20
03558G	bi-fuel										
03562G	bi-fuel	2776.00	82.40	142.40	72.22	96.35	187.11	168.57	12.35	14.84	6.07
03563G	bi-fuel	321.00	0.00	44.00	0.00	29.77	32.35	29.77	7.30	9.92	9.27
03570G	bi-fuel	4285.00									
03574G	bi-fuel	1523.00	112.70	0.00	98.78	0.00	112.70	98.78	13.51	13.51	6.49
03575G	bi-fuel	669.00	35.00	33.30	30.68	22.53	59.49	53.21	9.80	11.25	7.95
03577G	bi-fuel	2204.00	100.00	205.00	87.65	138.70	250.74	226.35	7.23	8.79	10.27
03578G	bi-fuel	1622.00	13.00	102.10	11.39	69.08	88.07	80.48	14.09	18.42	4.96
03579G	bi-fuel		8.00	30.50	7.01	20.64	30.43	27.65			
03625G	bi-fuel										
03626G	bi-fuel	3865.00	0.00	280.00	0.00	189.45	205.88	189.45	13.80	18.77	4.90
04355G	gasoline	1562.00	102.10		89.49		102.10	89.49	15.30	15.30	5.73
05414F	bi-fuel										
05415F	bi-fuel										
05418F	bi-fuel	1024.00	0.00	138.00	0.00	93.37	101.47	93.37	7.42	10.09	9.12
05419F	bi-fuel										
03644G	bi-fuel	495.00	28.70	47.20	25.16	26.16	63.41	51.32	6.52	7.81	10.37
03649G	bi-fuel	368.00	0.00	37.20	0.00	20.62	27.35	20.62	9.89	13.45	5.60
03651G	bi-fuel	775.00	18.00	73.00	15.78	40.46	71.68	56.24	8.52	10.81	7.26
03652G	bi-fuel	1024.00	0.00	78.00	0.00	43.24	57.35	43.24	13.13	17.85	4.22
03655G	bi-fuel	532.00	7.80	37.40	6.84	20.73	35.30	27.57	11.77	15.07	5.18
04353G	gasoline	1188.00	89.50		78.45		89.50	78.45	13.27	13.27	6.60
04354G	gasoline	1207.00	80.00		70.12		80.00	70.12	15.09	15.09	5.81
05971F	bi-fuel	1582.00	28.00	190.20	24.54	105.43	167.85	129.97	7.25	9.42	8.22
05972F	bi-fuel	445.00	12.70	20.30	11.13	11.25	27.63	22.38	13.48	16.11	5.03
05974F	bi-fuel	1433.00	18.00	104.00	15.78	57.65	94.47	73.42	11.75	15.17	5.12
05975F	bi-fuel	1734.00	21.00	160.00	18.41	88.69	138.65	107.09	9.58	12.51	6.18
05976F	bi-fuel	1429.00	41.70	111.10	36.55	61.58	123.39	98.13	9.35	11.58	6.87
05992F	bi-fuel	1956.00	23.00	203.50	20.16	112.80	172.63	132.96	8.64	11.33	6.80
05994F	bi-fuel	880.00	14.30	104.30	12.53	57.81	90.99	70.35	7.42	9.67	7.99
05995F	bi-fuel	814.00	0.00	90.00	0.00	49.89	66.18	49.89	9.04	12.30	6.13
05996F	bi-fuel	1484.00	20.00	76.00	17.53	42.13	75.88	59.66	15.46	19.56	4.02
05997F	bi-fuel	668.00	27.70	23.60	24.28	13.08	45.05	37.36	13.02	14.83	5.59
UT	gasoline	1189.00	93.30		81.78		93.30	81.78	12.74	12.74	6.88

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

September-97											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel	1431.00									
03558G	bi-fuel										
03562G	bi-fuel	3339.00									
03563G	bi-fuel	703.00	0.00	73.00	0.00	50.66	53.68	50.66	9.63	13.10	7.21
03570G	bi-fuel	3557.00	11.00	334.00	9.88	231.80	256.59	241.68	10.31	13.86	6.79
03574G	bi-fuel	1261.00	67.80	34.60	60.91	24.01	93.24	84.92	12.31	13.52	6.73
03575G	bi-fuel	262.00	9.00	35.00	8.09	24.29	34.74	32.38	5.95	7.54	12.36
03577G	bi-fuel	2517.00	66.00	154.40	59.29	107.15	179.53	166.45	11.42	14.02	6.61
03578G	bi-fuel	608.00	0.00	96.40	0.00	66.90	70.88	66.90	6.31	8.58	11.00
03579G	bi-fuel										
03625G	bi-fuel										
03626G	bi-fuel	4148.00	0.00	377.00	0.00	261.64	277.21	261.64	11.00	14.96	6.31
04355G	gasoline										
05414F	bi-fuel										
05415F	bi-fuel										
05418F	bi-fuel	901.00	0.00	145.00	0.00	100.63	106.62	100.63	6.21	8.45	11.17
05419F	bi-fuel										
03644G	bi-fuel	845.00	29.20	24.50	26.23	14.01	47.21	40.24	15.74	17.90	4.76
03649G	bi-fuel	1303.00	79.00	32.90	70.97	18.81	103.19	89.78	11.64	12.63	6.89
03651G	bi-fuel	555.00	0.00	20.00	0.00	11.43	14.71	11.43	27.75	37.74	2.06
03652G	bi-fuel	1113.00	0.00	78.00	0.00	44.59	57.35	44.59	14.27	19.41	4.01
03655G	bi-fuel	1105.00	10.10	111.90	9.07	63.97	92.38	73.05	9.06	11.96	6.61
04353G	gasoline	1125.00	87.90		78.97		87.90	78.97	12.80	12.80	7.02
04354G	gasoline	787.00	71.20		63.97		71.20	63.97	11.05	11.05	8.13
05971F	bi-fuel	1292.00	51.00	74.30	45.82	42.48	105.63	88.30	10.31	12.23	6.83
05972F	bi-fuel	788.00	23.10	21.40	20.75	12.23	38.84	32.99	17.71	20.29	4.19
05974F	bi-fuel	1742.00	9.00	153.00	8.09	87.47	121.50	95.56	10.75	14.34	5.49
05975F	bi-fuel	1786.00	111.00	53.00	99.72	30.30	149.97	130.02	10.89	11.91	7.28
05976F	bi-fuel	1499.00	68.70	57.00	61.72	32.59	110.61	94.31	11.93	13.55	6.29
05992F	bi-fuel	1690.00	0.00	193.60	0.00	110.68	142.35	110.68	8.73	11.87	6.55
05994F	bi-fuel	857.00	62.00	30.50	55.70	17.44	84.43	73.14	9.26	10.15	8.53
05995F	bi-fuel	1310.00	7.00	170.00	6.29	97.19	132.00	103.48	7.40	9.92	7.90
05996F	bi-fuel	1165.00	28.00	63.00	25.16	36.02	74.32	61.17	12.80	15.67	5.25
05997F	bi-fuel	2264.00	118.40	74.20	106.37	42.42	172.96	148.79	11.75	13.09	6.57
UT	gasoline	521.00	77.90		69.99		77.90	69.99	6.69	6.69	13.43

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

October-97											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel	2531.00	10.00	262.10	8.80	184.94	202.72	193.73	9.30	12.49	7.65
03558G	bi-fuel	3999.00	56.00	293.10	49.25	206.81	271.51	256.06	11.46	14.73	6.40
03562G	bi-fuel	1832.00	41.00	122.30	36.06	86.29	130.93	122.35	11.22	13.99	6.68
03563G	bi-fuel	1703.00	0.00	164.00	0.00	115.72	120.59	115.72	10.38	14.12	6.79
03570G	bi-fuel	2949.00	51.00	283.90	44.85	200.32	259.75	245.17	8.81	11.35	8.31
03574G	bi-fuel	2646.00	87.00	73.80	76.52	52.07	141.26	128.59	16.46	18.73	4.86
03575G	bi-fuel	646.00	0.00	45.40	0.00	32.03	33.38	32.03	14.23	19.35	4.96
03577G	bi-fuel					0.00					
03578G	bi-fuel	658.00	0.00	35.70	0.00	25.19	26.25	25.19	18.43	25.07	3.83
03579G	bi-fuel										
03625G	bi-fuel										
03626G	bi-fuel	4360.00	0.00	414.00	0.00	292.12	304.41	292.12	10.53	14.32	6.70
04355G	gasoline										
05414F	bi-fuel										
05415F	bi-fuel										
05418F	bi-fuel	669.00	0.00	73.00	0.00	51.51	53.68	51.51	9.16	12.46	7.70
05419F	bi-fuel										
03644G	bi-fuel	937.00	47.00	71.60	41.34	41.76	99.65	83.10	7.90	9.40	8.87
03649G	bi-fuel	966.00	5.00	94.20	4.40	54.95	74.26	59.34	9.74	13.01	6.14
03651G	bi-fuel	1048.00	28.00	81.00	24.63	47.25	87.56	71.87	9.61	11.97	6.86
03652G	bi-fuel	481.00	20.00	49.00	17.59	28.58	56.03	46.17	6.97	8.58	9.60
03655G	bi-fuel	903.00	0.00	74.60	0.00	43.51	54.85	43.51	12.10	16.46	4.82
04353G	gasoline	1123.00	88.00		77.40		88.00	77.40	12.76	12.76	6.89
04354G	gasoline	1128.00	73.10		64.29		73.10	64.29	15.43	15.43	5.70
05971F	bi-fuel	887.00	10.00	61.20	8.80	35.70	55.00	44.49	12.46	16.13	5.02
05972F	bi-fuel	514.00	12.00	14.00	10.55	8.17	22.29	18.72	19.77	23.06	3.64
05974F	bi-fuel	1791.00	34.00	127.00	29.90	74.08	127.38	103.98	11.12	14.06	5.81
05975F	bi-fuel	2057.00	154.00	25.00	135.44	14.58	172.38	150.03	11.49	11.93	7.29
05976F	bi-fuel	956.00	20.90	77.10	18.38	44.97	77.59	63.35	9.76	12.32	6.63
05992F	bi-fuel	2021.00	29.00	119.70	25.51	69.82	117.01	95.33	13.59	17.27	4.72
05994F	bi-fuel	1384.00	0.00	141.10	0.00	82.30	103.75	82.30	9.81	13.34	5.95
05995F	bi-fuel	1665.00	23.00	125.00	20.23	72.91	114.91	93.14	11.25	14.49	5.59
05996F	bi-fuel	2069.00	20.00	180.00	17.59	104.99	152.35	122.58	10.35	13.58	5.92
05997F	bi-fuel	1599.00	28.40	142.40	24.98	83.06	133.11	108.04	9.36	12.01	6.76
UT	gasoline	2791.00	156.00		137.20		156.00	137.20	17.89	17.89	4.92

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

November-97											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel	1134.00	26.00	95.00	21.95	63.42	95.85	85.38	9.37	11.83	7.53
03558G	bi-fuel	2629.00	16.00	165.00	13.51	110.15	137.32	123.66	14.52	19.14	4.70
03562G	bi-fuel	1702.00	19.00	108.50	16.04	72.43	98.78	88.48	13.35	17.23	5.20
03563G	bi-fuel	1645.00	0.00	80.00	0.00	53.41	58.82	53.41	20.56	27.97	3.25
03570G	bi-fuel	3138.00	50.30	247.40	42.47	165.16	232.21	207.64	10.54	13.51	6.62
03574G	bi-fuel	2071.00	83.70	89.70	70.68	59.88	149.66	130.56	11.94	13.84	6.30
03575G	bi-fuel	545.00	0.00	92.00	0.00	61.42	67.65	61.42	5.92	8.06	11.27
03577G	bi-fuel										
03578G	bi-fuel	243.00	0.00	35.60	0.00	23.77	26.18	23.77	6.83	9.28	9.78
03579G	bi-fuel										
03625G	bi-fuel										
03626G	bi-fuel	2387.00	0.00	181.00	0.00	120.84	133.09	120.84	13.19	17.94	5.06
04355G	gasoline										
05414F	bi-fuel										
05415F	bi-fuel										
05418F	bi-fuel	650.00	0.00	71.00	0.00	47.40	52.21	47.40	9.15	12.45	7.29
05419F	bi-fuel	2225.00	0.00	183.90	0.00	122.77	135.22	122.77	12.10	16.45	5.52
03644G	bi-fuel	1038.00	24.40	35.10	20.60	19.14	50.21	39.74	17.45	20.67	3.83
03649G	bi-fuel	618.00	9.00	37.00	7.60	20.18	36.21	27.78	13.43	17.07	4.49
03651G	bi-fuel	1063.00	32.00	103.00	27.02	56.17	107.74	83.19	7.87	9.87	7.83
03652G	bi-fuel	368.00	0.00	15.00	0.00	8.18	11.03	8.18	24.53	33.37	2.22
03655G	bi-fuel	124.00	0.00	22.00	0.00	12.00	16.18	12.00	5.64	7.67	9.67
04353G	gasoline	766.00	46.00		38.84		46.00	38.84	16.65	16.65	5.07
04354G	gasoline	962.00	47.50		40.11		47.50	40.11	20.25	20.25	4.17
05971F	bi-fuel	507.00	0.00	39.60	0.00	21.59	29.12	21.59	12.80	17.41	4.26
05972F	bi-fuel	195.00	0.00	20.40	0.00	11.12	15.00	11.12	9.56	13.00	5.70
05974F	bi-fuel	1192.00	0.00	100.00	0.00	54.53	73.53	54.53	11.92	16.21	4.57
05975F	bi-fuel	1263.00	108.00	24.00	91.20	13.09	125.65	104.28	9.57	10.05	8.26
05976F	bi-fuel	861.00	9.00	75.80	7.60	41.33	64.74	48.93	10.15	13.30	5.68
05992F	bi-fuel	1773.00	15.00	174.50	12.67	95.15	143.31	107.82	9.36	12.37	6.08
05994F	bi-fuel	1023.00	12.50	90.30	10.56	49.24	78.90	59.80	9.95	12.97	5.85
05995F	bi-fuel	1421.00	9.00	140.00	7.60	76.34	111.94	83.94	9.54	12.69	5.91
05996F	bi-fuel	1511.00	0.00	128.00	0.00	69.80	94.12	69.80	11.80	16.05	4.62
05997F	bi-fuel	1602.00	8.00	103.30	6.76	56.33	83.96	63.08	14.39	19.08	3.94
UT	gasoline	2021.00	116.80		98.63		116.80	98.63	17.30	17.30	4.88

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

December-97											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel										
03558G	bi-fuel	2961.00	14.00	264.40	11.68	170.11	208.41	181.80	10.64	14.21	6.14
03562G	bi-fuel	3203.00	96.00	210.40	80.11	135.37	250.71	215.48	10.45	12.78	6.73
03563G	bi-fuel	912.00	0.00	70.00	0.00	45.04	51.47	45.04	13.03	17.72	4.94
03570G	bi-fuel	1973.00	37.00	151.00	30.88	97.15	148.03	128.03	10.49	13.33	6.49
03574G	bi-fuel	1677.00	55.80	56.70	46.57	36.48	97.49	83.05	14.91	17.20	4.95
03575G	bi-fuel	853.00	0.00	48.60	0.00	31.27	35.74	31.27	17.55	23.87	3.67
03577G	bi-fuel	887.00	34.00	72.50	28.37	46.65	87.31	75.02	8.33	10.16	8.46
03578G	bi-fuel	756.00	0.00	70.10	0.00	45.10	51.54	45.10	10.78	14.67	5.97
03579G	bi-fuel	877.00	14.00	62.20	11.68	40.02	59.74	51.70	11.51	14.68	5.90
03625G	bi-fuel										
03626G	bi-fuel										
04355G	gasoline										
05414F	bi-fuel										
05415F	bi-fuel										
05418F	bi-fuel	536.00	0.00	73.00	0.00	46.97	53.68	46.97	7.34	9.99	8.76
05419F	bi-fuel										
03644G	bi-fuel	1011.00	22.80	67.70	19.03	35.28	72.58	54.31	11.17	13.93	5.37
03649G	bi-fuel	936.00	0.00	105.40	0.00	54.92	77.50	54.92	8.88	12.08	5.87
03651G	bi-fuel	484.00	20.00	41.00	16.69	21.37	50.15	38.06	7.93	9.65	7.86
03652G	bi-fuel	363.00	0.00	41.00	0.00	21.37	30.15	21.37	8.85	12.04	5.89
03655G	bi-fuel	167.00									
04353G	gasoline	1137.00	81.20		67.76		81.20	67.76	14.00	14.00	5.96
04354G	gasoline	1128.00	64.30		53.66		64.30	53.66	17.54	17.54	4.76
05971F	bi-fuel	797.00	15.00	57.50	12.52	29.96	57.28	42.48	10.99	13.91	5.33
05972F	bi-fuel	350.00	10.70	0.00	8.93	0.00	10.70	8.93	32.71	32.71	2.55
05974F	bi-fuel	1641.00	27.50	115.00	22.95	59.93	112.06	82.88	11.52	14.64	5.05
05975F	bi-fuel	1912.00	0.00	198.00	0.00	103.18	145.59	103.18	9.66	13.13	5.40
05976F	bi-fuel		0.00	5.00	0.00	2.61	3.68	2.61	0.00		
05992F	bi-fuel	1167.00	6.00	103.00	5.01	53.67	81.74	58.68	10.71	14.28	5.03
05994F	bi-fuel	1140.00	10.50	119.10	8.76	62.06	98.07	70.83	8.80	11.62	6.21
05995F	bi-fuel	1741.00	9.00	157.00	7.51	81.81	124.44	89.32	10.49	13.99	5.13
05996F	bi-fuel	1703.00	0.00	170.00	0.00	88.59	125.00	88.59	10.02	13.62	5.20
05997F	bi-fuel	432.00	0.00	65.80	0.00	34.29	48.38	34.29	6.57	8.93	7.94
UT	gasoline	3015.00	210.80		175.91		210.80	175.91	14.30	14.30	5.83

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

January-98											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel										
03558G	bi-fuel	3067.00									
03562G	bi-fuel	1392.00									
03563G	bi-fuel	955.00	0.00	79.00	0.00	48.16	58.09	48.16	12.09	16.44	5.04
03570G	bi-fuel	1690.00	10.00	108.00	8.13	65.84	89.41	73.97	14.32	18.90	4.38
03574G	bi-fuel	2083.00									
03575G	bi-fuel										
03577G	bi-fuel	1585.00	52.00	81.00	42.28	49.38	111.56	91.65	11.92	14.21	5.78
03578G	bi-fuel	780.00	0.00	74.50	0.00	45.42	54.78	45.42	10.47	14.24	5.82
03579G	bi-fuel	341.00		42.00	0.00	25.60	30.88	25.60	8.12	11.04	7.51
03625G	bi-fuel										
03626G	bi-fuel										
04355G	gasoline										
05414F	bi-fuel										
05415F	bi-fuel										
05418F	bi-fuel	500.00	0.00	66.00	0.00	40.23	48.53	40.23	7.58	10.30	8.05
05419F	bi-fuel	2041.00	11.00	187.60	8.94	114.36	148.94	123.30	10.28	13.70	6.04
03644G	bi-fuel	1273.00	35.50	121.00	28.86	58.96	124.47	87.82	8.13	10.23	6.90
03649G	bi-fuel	867.00	10.00	63.40	8.13	30.89	56.62	39.02	11.81	15.31	4.50
03651G	bi-fuel	654.00	19.00	62.00	15.45	30.21	64.59	45.66	8.07	10.13	6.98
03652G	bi-fuel	1171.00	12.00	84.00	9.76	40.93	73.76	50.69	12.20	15.87	4.33
03655G	bi-fuel	132.00	0.00	20.80	0.00	10.14	15.29	10.14	6.35	8.63	7.68
04353G	gasoline	1829.00	104.60		85.04		104.60	85.04	17.49	17.49	4.65
04354G	gasoline	1126.00	54.60		44.39		54.60	44.39	20.62	20.62	3.94
05971F	bi-fuel	420.00	22.00	21.00	17.89	10.23	37.44	28.12	9.77	11.22	6.70
05972F	bi-fuel	465.00	11.20	21.60	9.11	10.53	27.08	19.63	14.18	17.17	4.22
05974F	bi-fuel	1554.00	0.00	101.00	0.00	49.22	74.26	49.22	15.39	20.93	3.17
05975F	bi-fuel	1678.00	0.00	172.00	0.00	83.82	126.47	83.82	9.76	13.27	4.99
05976F	bi-fuel	1045.00	8.20	82.20	6.67	40.06	68.64	46.72	11.56	15.22	4.47
05992F	bi-fuel	902.00	0.00	99.00	0.00	48.24	72.79	48.24	9.11	12.39	5.35
05994F	bi-fuel	1407.00	12.00	117.30	9.76	57.16	98.25	66.92	10.88	14.32	4.76
05995F	bi-fuel	1816.00	0.00	122.00	0.00	59.45	89.71	59.45	14.89	20.24	3.27
05996F	bi-fuel	1491.00	22.00	109.00	17.89	53.12	102.15	71.00	11.38	14.60	4.76
05997F	bi-fuel	986.00	0.00	88.10	0.00	42.93	64.78	42.93	11.19	15.22	4.35
UT	gasoline	2915.00	181.00		147.15		181.00	147.15	16.10	16.10	5.05

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

February-98											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel	1715.00	0.00	179.00	0.00	108.31	131.62	108.31	9.58	13.03	6.32
03558G	bi-fuel	3083.00	18.00	271.00	14.26	163.98	217.26	178.24	10.67	14.19	5.78
03562G	bi-fuel	2716.00	78.00	141.10	61.78	85.38	181.75	147.16	12.40	14.94	5.42
03563G	bi-fuel	1158.00	0.00	120.00	0.00	72.61	88.24	72.61	9.65	13.12	6.27
03570G	bi-fuel	1396.00	6.00	84.60	4.75	51.19	68.21	55.94	15.41	20.47	4.01
03574G	bi-fuel	1103.00	0.00	101.00	0.00	61.12	74.26	61.12	10.92	14.85	5.54
03575G	bi-fuel	1212.00	18.00	91.40	14.26	55.31	85.21	69.56	11.08	14.22	5.74
03577G	bi-fuel	780.00	50.00	40.00	39.61	24.20	79.41	63.81	8.67	9.82	8.18
03578G	bi-fuel	785.00	18.00	71.10	14.26	43.02	70.28	57.28	8.81	11.17	7.30
03579G	bi-fuel										
03625G	bi-fuel										
03626G	bi-fuel	4377.00	0.00	380.00	0.00	229.94	279.41	229.94	11.52	15.67	5.25
04355G	gasoline										
05414F	bi-fuel										
05415F	bi-fuel										
05418F	bi-fuel										
05419F	bi-fuel	2095.00	0.00	82.50	0.00	49.92	60.66	49.92	25.39	34.54	2.38
03644G	bi-fuel	913.00	0.00	72.00	0.00	34.76	52.94	34.76	12.68	17.25	3.81
03649G	bi-fuel	768.00	0.00	71.70	0.00	34.62	52.72	34.62	10.71	14.57	4.51
03651G	bi-fuel	899.00	6.00	41.40	4.75	19.99	36.44	24.74	18.97	24.67	2.75
03652G	bi-fuel	926.00	0.00	92.00	0.00	44.42	67.65	44.42	10.07	13.69	4.80
03655G	bi-fuel	220.00	0.00	21.00	0.00	10.14	15.44	10.14	10.48	14.25	4.61
04353G	gasoline	1393.00	121.60		96.32		121.60	96.32	11.46	11.46	6.91
04354G	gasoline	988.00	64.90		51.41		64.90	51.41	15.22	15.22	5.20
05971F	bi-fuel	407.00	0.00	20.00	0.00	9.66	14.71	9.66	20.35	27.68	2.37
05972F	bi-fuel	446.00	27.70	19.40	21.94	9.37	41.96	31.31	9.47	10.63	7.02
05974F	bi-fuel	1544.00	16.00	108.00	12.67	52.14	95.41	64.82	12.45	16.18	4.20
05975F	bi-fuel	1964.00	7.00	188.00	5.54	90.77	145.24	96.31	10.07	13.52	4.90
05976F	bi-fuel	1415.00	0.00	136.80	0.00	66.05	100.59	66.05	10.34	14.07	4.67
05992F	bi-fuel	1142.00	7.00	82.10	5.54	39.64	67.37	45.18	12.82	16.95	3.96
05994F	bi-fuel	1764.00	10.00	160.90	7.92	77.68	128.31	85.60	10.32	13.75	4.85
05995F	bi-fuel	1446.00	0.00	159.00	0.00	76.77	116.91	76.77	9.09	12.37	5.31
05996F	bi-fuel	1357.00	0.00	172.00	0.00	83.04	126.47	83.04	7.89	10.73	6.12
05997F	bi-fuel	555.00	0.00	48.20	0.00	23.27	35.44	23.27	11.51	15.66	4.19
UT	gasoline	1427.00	94.60		74.93		94.60	74.93	15.08	15.08	5.25

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

March-98											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel	1833.00	38.00	126.00	29.13	73.34	130.65	102.48	11.18	14.03	5.59
03558G	bi-fuel		0.00	47.00	0.00	27.36	34.56	27.36			
03562G	bi-fuel	1300.00	21.00	88.50	16.10	51.52	86.07	67.61	11.87	15.10	5.20
03563G	bi-fuel	968.00	0.00	44.00	0.00	25.61	32.35	25.61	22.00	29.92	2.65
03570G	bi-fuel	26.00									
03574G	bi-fuel	1769.00	89.00	43.40	68.23	25.26	120.91	93.49	13.36	14.63	5.28
03575G	bi-fuel	1055.00	0.00	92.10	0.00	53.61	67.72	53.61	11.45	15.58	5.08
03577G	bi-fuel	1470.00	71.00	128.00	54.43	74.51	165.12	128.94	7.39	8.90	8.77
03578G	bi-fuel	792.00	0.00	106.20	0.00	61.82	78.09	61.82	7.46	10.14	7.81
03579G	bi-fuel										
03625G	bi-fuel										
03626G	bi-fuel	4837.00	0.00	432.00	0.00	251.47	317.65	251.47	11.20	15.23	5.20
04355G	gasoline										
05414F	bi-fuel										
05415F	bi-fuel	991.00	52.00	42.00	39.86	24.45	82.88	64.31	10.54	11.96	6.49
05418F	bi-fuel										
05419F	bi-fuel	2149.00	0.00	149.80	0.00	87.20	110.15	87.20	14.35	19.51	4.06
03644G	bi-fuel	741.00	17.00	79.00	13.03	36.32	75.09	49.36	7.72	9.87	6.66
03649G	bi-fuel	820.00	0.00	75.00	0.00	52.43	55.15	52.43	10.93	14.87	6.39
03651G	bi-fuel	476.00	8.00	43.40	6.13	30.34	39.91	36.47	9.26	11.93	7.66
03652G	bi-fuel	637.00	0.00	44.00	0.00	30.76	32.35	30.76	14.48	19.69	4.83
03655G	bi-fuel	268.00	9.10	21.00	6.98	14.68	24.54	21.66	8.90	10.92	8.08
04353G	gasoline	2006.00	143.70		110.16		143.70	110.16	13.96	13.96	5.49
04354G	gasoline	897.00	51.60		39.56		51.60	39.56	17.38	17.38	4.41
05971F	bi-fuel	887.00	36.00	61.50	27.60	42.99	81.22	70.59	9.10	10.92	7.96
05972F	bi-fuel	511.00	35.20	0.00	26.98	0.00	35.20	26.98	14.52	14.52	5.28
05974F	bi-fuel	1062.00	16.70	82.00	12.80	57.32	76.99	70.12	10.76	13.79	6.60
05975F	bi-fuel	906.00	0.00	56.00	0.00	39.14	41.18	39.14	16.18	22.00	4.32
05976F	bi-fuel	1348.00	0.00	132.20	0.00	92.41	97.21	92.41	10.20	13.87	6.86
05992F	bi-fuel	971.00	0.00	110.30	0.00	77.10	81.10	77.10	8.80	11.97	7.94
05994F	bi-fuel	1362.00	8.30	113.40	6.36	79.27	91.68	85.63	11.19	14.86	6.29
05995F	bi-fuel	938.00	12.00	118.00	9.20	82.48	98.76	91.68	7.22	9.50	9.77
05996F	bi-fuel	989.00	0.00	71.00	0.00	49.63	52.21	49.63	13.93	18.94	5.02
05997F	bi-fuel	1275.00	0.00	136.60	0.00	95.48	100.44	95.48	9.33	12.69	7.49
UT	gasoline	1889.00	81.60		62.55		81.60	62.55	23.15	23.15	3.31

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

April-98											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel	2168.00	18.00	205.00	13.33	122.59	168.74	135.92	9.72	12.85	6.27
03558G	bi-fuel										
03562G	bi-fuel	3508.00	116.00	130.90	85.89	78.28	212.25	164.16	14.21	16.53	4.68
03563G	bi-fuel	544.00	0.00	47.00	0.00	28.11	34.56	28.11	11.57	15.74	5.17
03570G	bi-fuel	3468.00	18.00	307.80	13.33	184.06	244.32	197.39	10.64	14.19	5.69
03574G	bi-fuel	2926.00	11.10	42.00	8.22	25.12	41.98	33.33	55.10	69.70	1.14
03575G	bi-fuel	1638.00	13.00	139.50	9.63	83.42	115.57	93.05	10.74	14.17	5.68
03577G	bi-fuel	1334.00	64.00	92.00	47.39	55.02	131.65	102.40	8.55	10.13	7.68
03578G	bi-fuel	867.00	16.00	104.20	11.85	62.31	92.62	74.16	7.21	9.36	8.55
03579G	bi-fuel										
03625G	bi-fuel										
03626G	bi-fuel	4195.00	0.00	337.00	0.00	201.53	247.79	201.53	12.45	16.93	4.80
04355G	gasoline										
05414F	bi-fuel										
05415F	bi-fuel	1416.00	87.00	40.00	64.41	23.92	116.41	88.33	11.15	12.16	6.24
05418F	bi-fuel										
05419F	bi-fuel	2637.00	8.00	188.30	5.92	112.60	146.46	118.53	13.43	18.01	4.49
03644G	bi-fuel	750.00	26.00	26.00	19.25	12.37	45.12	31.62	14.42	16.62	4.22
03649G	bi-fuel	909.00	22.20	21.00	16.44	9.99	37.64	26.43	21.04	24.15	2.91
03651G	bi-fuel	1225.00	32.00	102.40	23.69	48.71	107.29	72.40	9.11	11.42	5.91
03652G	bi-fuel	860.00	0.00	63.00	0.00	29.97	46.32	29.97	13.65	18.57	3.48
03655G	bi-fuel	150.00	19.40	0.00	14.36	0.00	19.40	14.36	7.73	7.73	9.58
04353G	gasoline	1035.00	68.00		50.35		68.00	50.35	15.22	15.22	4.86
04354G	gasoline	916.00	33.50		24.80		33.50	24.80	27.34	27.34	2.71
05971F	bi-fuel	1445.00	34.00	133.50	25.17	63.51	132.16	88.68	8.63	10.93	6.14
05972F	bi-fuel	539.00	13.30	0.00	9.85	0.00	13.30	9.85	40.53	40.53	1.83
05974F	bi-fuel										
05975F	bi-fuel	1551.00	74.00	15.00	54.79	7.14	85.03	61.93	17.43	18.24	3.99
05976F	bi-fuel	528.00	35.00	40.00	25.91	19.03	64.41	44.94	7.04	8.20	8.51
05992F	bi-fuel	1389.00	0.00	146.60	0.00	69.74	107.79	69.74	9.47	12.89	5.02
05994F	bi-fuel	1214.00	67.00	85.50	49.61	40.67	129.87	90.28	7.96	9.35	7.44
05995F	bi-fuel	1873.00	30.00	162.00	22.21	77.06	149.12	99.28	9.76	12.56	5.30
05996F	bi-fuel	282.00	12.00	18.00	8.88	8.56	25.24	17.45	9.40	11.17	6.19
05997F	bi-fuel	2300.00	112.40	90.60	83.22	43.10	179.02	126.32	11.33	12.85	5.49
UT	gasoline	1635.00	90.10		66.71		90.10	66.71	18.15	18.15	4.08

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

May-98											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel	1898.00		184.20	0.00	107.15	135.44	107.15	10.30	14.01	5.65
03558G	bi-fuel			113.70	0.00	66.14	83.60	66.14			
03562G	bi-fuel	2524.00	65.00	97.10	48.37	56.48	136.40	104.86	15.57	18.50	4.15
03563G	bi-fuel				0.00	0.00	0.00	0.00			
03570G	bi-fuel				0.00	0.00	0.00	0.00			
03574G	bi-fuel	1447.00	67.80	33.50	50.46	19.49	92.43	69.94	14.28	15.65	4.83
03575G	bi-fuel	1158.00		111.80	0.00	65.03	82.21	65.03	10.36	14.09	5.62
03577G	bi-fuel	1216.00	65.00	123.00	48.37	71.55	155.44	119.92	6.47	7.82	9.86
03578G	bi-fuel	575.00		91.29	0.00	53.10	67.13	53.10	6.30	8.57	9.24
03579G	bi-fuel										
03625G	bi-fuel										
03626G	bi-fuel	4602.00		368.00	0.00	214.07	270.59	214.07	12.51	17.01	4.65
04355G	gasoline										
05414F	bi-fuel										
05415F	bi-fuel		9.00	40.00	6.70	23.27	38.41	29.97			
05418F	bi-fuel				0.00	0.00	0.00	0.00			
05419F	bi-fuel	2952.70	42.00	218.70	31.26	127.22	202.81	158.47	11.33	14.56	5.37
03644G	bi-fuel										
03649G	bi-fuel	948.00	11.00	106.00	8.19	48.70	88.94	56.88	8.10	10.66	6.00
03651G	bi-fuel	1340.00	13.00	101.00	9.67	46.40	87.26	56.07	11.75	15.36	4.18
03652G	bi-fuel	710.00		70.00	0.00	32.16	51.47	32.16	10.14	13.79	4.53
03655G	bi-fuel	311.00	19.50		14.51	0.00	19.50	14.51	15.95	15.95	4.67
04353G	gasoline	1698.00	118.60		88.26		118.60	88.26	14.32	14.32	5.20
04354G	gasoline	906.00	68.50		50.98		68.50	50.98	13.23	13.23	5.63
05971F	bi-fuel	708.00	15.00	78.00	11.16	35.83	72.35	47.00	7.61	9.79	6.64
05972F	bi-fuel										
05974F	bi-fuel	2200.00		187.00	0.00	85.91	137.50	85.91	11.76	16.00	3.90
05975F	bi-fuel	1698.00	16.00	163.00	11.91	74.88	135.85	86.79	9.49	12.50	5.11
05976F	bi-fuel	1012.00		109.00	0.00	50.07	80.15	50.07	9.28	12.63	4.95
05992F	bi-fuel	1171.00	18.00	104.70	13.40	48.10	94.99	61.49	9.54	12.33	5.25
05994F	bi-fuel	446.00	11.00		8.19	0.00	11.00	8.19	40.55	40.55	1.84
05995F	bi-fuel	1748.00	14.00	175.00	10.42	80.40	142.68	90.81	9.25	12.25	5.20
05996F	bi-fuel	487.00		38.70	0.00	17.78	28.46	17.78	12.58	17.11	3.65
05997F	bi-fuel	760.00	14.00	96.90	10.42	44.52	85.25	54.93	6.85	8.91	7.23
UT	gasoline	2849.00	263.32		195.96		263.32	195.96	10.82	10.82	6.88

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

June-98											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel	1658.00	7.00	184.10	5.25	101.60	142.37	106.85	8.68	11.65	6.44
03558G	bi-fuel		0.00	111.00	0.00	61.26	81.62	61.26			
03562G	bi-fuel										
03563G	bi-fuel										
03570G	bi-fuel										
03574G	bi-fuel	2691.00	64.70	35.00	48.49	19.32	90.44	67.81	26.99	29.76	2.52
03575G	bi-fuel	2075.00	27.00	129.70	20.24	71.58	122.37	91.82	13.24	16.96	4.42
03577G	bi-fuel	1473.00	62.00	120.00	46.47	66.23	150.24	112.70	8.09	9.80	7.65
03578G	bi-fuel										
03579G	bi-fuel										
03625G	bi-fuel										
03626G	bi-fuel	3424.00	0.00	328.00	0.00	181.02	241.18	181.02	10.44	14.20	5.29
04355G	gasoline										
05414F	bi-fuel										
05415F	bi-fuel										
05418F	bi-fuel	124.00	12.00		8.99	0.00	12.00	8.99	10.33	10.33	7.25
05419F	bi-fuel	2057.00	37.00	187.90	27.73	103.70	175.16	131.43	9.15	11.74	6.39
03644G	bi-fuel	564.00	18.00	66.00	13.49	28.35	66.53	41.84	6.71	8.48	7.42
03649G	bi-fuel	852.00	0.00	74.00	0.00	31.79	54.41	31.79	11.51	15.66	3.73
03651G	bi-fuel	1572.00	45.00	102.20	33.73	43.91	120.15	77.63	10.68	13.08	4.94
03652G	bi-fuel	949.00	11.00	44.00	8.24	18.90	43.35	27.15	17.25	21.89	2.86
03655G	bi-fuel	285.00	9.80	0.00	7.35	0.00	9.80	7.35	29.08	29.08	2.58
04353G	gasoline	1662.00	114.00		85.44		114.00	85.44	14.58	14.58	5.14
04354G	gasoline	1079.00	83.40		62.51		83.40	62.51	12.94	12.94	5.79
05971F	bi-fuel	553.00	19.00	58.00	14.24	24.92	61.65	39.16	7.18	8.97	7.08
05972F	bi-fuel										
05974F	bi-fuel	1985.00	18.00	212.00	13.49	91.08	173.88	104.57	8.63	11.42	5.27
05975F	bi-fuel	1414.00	14.00	190.00	10.49	81.62	153.71	92.12	6.93	9.20	6.51
05976F	bi-fuel	1170.00	8.00	135.00	6.00	58.00	107.26	63.99	8.18	10.91	5.47
05992F	bi-fuel	871.00	20.00	83.10	14.99	35.70	81.10	50.69	8.45	10.74	5.82
05994F	bi-fuel	1665.00	8.20	189.30	6.15	81.32	147.39	87.47	8.43	11.30	5.25
05995F	bi-fuel	1266.00	2.00	174.00	1.50	74.75	129.94	76.25	7.19	9.74	6.02
05996F	bi-fuel	1751.00	0.00	179.90	0.00	77.29	132.28	77.29	9.73	13.24	4.41
05997F	bi-fuel	336.00	15.00	36.50	11.24	15.68	41.84	26.92	6.52	8.03	8.01
UT	gasoline	7312.00	523.56		392.41		523.56	392.41	13.97	13.97	5.37

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

July-98											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel	1327.00									
03558G	bi-fuel	1167.00	0.00	35.00	0.00	19.36	25.74	19.36	33.34	45.35	1.66
03562G	bi-fuel		31.00	25.10	22.75	13.88	49.46	36.63			
03563G	bi-fuel										
03570G	bi-fuel		12.00	47.00	8.81	26.00	46.56	34.80			
03574G	bi-fuel	2258.00	107.60	143.40	78.97	79.31	213.04	158.28	9.00	10.60	7.01
03575G	bi-fuel	496.00	7.00	44.00	5.14	24.34	39.35	29.47	9.73	12.60	5.94
03577G	bi-fuel	1356.00	91.00	71.00	66.78	39.27	143.21	106.06	8.37	9.47	7.82
03578G	bi-fuel	2634.00		307.00	0.00	169.80	225.74	169.80	8.58	11.67	6.45
03579G	bi-fuel										
03625G	bi-fuel										
03626G	bi-fuel	4313.00	0.00	350.00	0.00	193.59	257.35	193.59	12.32	16.76	4.49
04355G	gasoline										
05414F	bi-fuel										
05415F	bi-fuel										
05418F	bi-fuel	1793.00		75.10	0.00	41.54	55.22	41.54	23.87	32.47	2.32
05419F	bi-fuel	3051.00	45.60	97.60	33.47	53.98	117.36	87.45	21.31	26.00	2.87
03644G	bi-fuel	771.00	0.00	92.00	0.00	39.63	67.65	39.63	8.38	11.40	5.14
03649G	bi-fuel	1402.00	8.00	135.00	5.87	58.16	107.26	64.03	9.80	13.07	4.57
03651G	bi-fuel	2071.00	10.00	227.30	7.34	97.92	177.13	105.26	8.73	11.69	5.08
03652G	bi-fuel	1407.00	7.00	148.00	5.14	63.76	115.82	68.90	9.08	12.15	4.90
03655G	bi-fuel	315.00	0.00	54.50	0.00	23.48	40.07	23.48	5.78	7.86	7.45
04353G	gasoline	1153.00	94.00		68.99		94.00	68.99	12.27	12.27	5.98
04354G	gasoline	927.00	62.80		46.09		62.80	46.09	14.76	14.76	4.97
05971F	bi-fuel	453.00	13.00	105.60	9.54	45.49	90.65	55.03	3.82	5.00	12.15
05972F	bi-fuel		0.00	23.70	0.00	10.21	17.43	10.21	0.00		
05974F	bi-fuel	2041.00	0.00	203.00	0.00	87.45	149.26	87.45	10.05	13.67	4.28
05975F	bi-fuel	1152.00	7.00	66.00	5.14	28.43	55.53	33.57	15.78	20.75	2.91
05976F	bi-fuel	764.00	5.50	93.00	4.04	40.06	73.88	44.10	7.76	10.34	5.77
05992F	bi-fuel	2150.00	20.00	257.10	14.68	110.76	209.04	125.44	7.76	10.28	5.83
05994F	bi-fuel	2680.00	0.00	232.60	0.00	100.20	171.03	100.20	11.52	15.67	3.74
05995F	bi-fuel	721.00	0.00	86.00	0.00	37.05	63.24	37.05	8.38	11.40	5.14
05996F	bi-fuel	575.00	16.60	37.50	12.18	16.16	44.17	28.34	10.63	13.02	4.93
05997F	bi-fuel	2187.00	47.10	185.90	34.57	80.09	183.79	114.65	9.39	11.90	5.24
UT	gasoline	1899.40	113.29		83.15		113.29	83.15	16.77	16.77	4.38

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

August-98											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel										
03558G	bi-fuel										
03562G	bi-fuel	3483.00	124.00	118.20	87.46	64.84	210.91	152.30	14.38	16.51	4.37
03563G	bi-fuel										
03570G	bi-fuel	1261.00									
03574G	bi-fuel	2713.00	52.00	75.00	36.68	41.15	107.15	77.82	21.36	25.32	2.87
03575G	bi-fuel	2761.00		302.20	0.00	165.79	222.21	165.79	9.14	12.43	6.00
03577G	bi-fuel	1291.00	44.00	123.00	31.03	67.48	134.44	98.51	7.73	9.60	7.63
03578G	bi-fuel	1585.00	108.00		76.17	0.00	108.00	76.17	14.68	14.68	4.81
03579G	bi-fuel	913.00		77.60	0.00	42.57	57.06	42.57	11.77	16.00	4.66
03625G	bi-fuel										
03626G	bi-fuel	2112.00	0.00	223.00	0.00	122.34	163.97	122.34	9.47	12.88	5.79
04355G	gasoline										
05414F	bi-fuel	1137.00		117.70	0.00	64.57	86.54	64.57	9.66	13.14	5.68
05415F	bi-fuel	2222.00		216.00	0.00	118.50	158.82	118.50	10.29	13.99	5.33
05418F	bi-fuel	541.00	30.00	40.80	21.16	22.38	60.00	43.54	7.64	9.02	8.05
05419F	bi-fuel	2281.00		210.00	0.00	115.21	154.41	115.21	10.86	14.77	5.05
03644G	bi-fuel	1037.00	71.00	0.00	50.08	0.00	71.00	50.08	14.61	14.61	4.83
03649G	bi-fuel	1087.00	93.00	25.00	65.59	10.66	111.38	76.25	9.21	9.76	7.01
03651G	bi-fuel	2386.00	109.00	0.00	76.88	0.00	109.00	76.88	21.89	21.89	3.22
03652G	bi-fuel	1435.00	113.00	0.00	79.70	0.00	113.00	79.70	12.70	12.70	5.55
03655G	bi-fuel	310.00	41.80	0.00	29.48	0.00	41.80	29.48	7.42	7.42	9.51
04353G	gasoline	1133.00	104.00		73.35		104.00	73.35	10.89	10.89	6.47
04354G	gasoline	1561.00	107.40		75.75		107.40	75.75	14.53	14.53	4.85
05971F	bi-fuel	590.00	110.00	18.00	77.58	7.67	123.24	85.26	4.61	4.79	14.45
05972F	bi-fuel	316.00	17.30	0.00	12.20	0.00	17.30	12.20	18.27	18.27	3.86
05974F	bi-fuel	1384.00	88.00	0.00	62.07	0.00	88.00	62.07	15.73	15.73	4.48
05975F	bi-fuel	1513.00	14.00	199.00	9.87	84.83	160.32	94.71	7.10	9.44	6.26
05976F	bi-fuel	1296.00	0.00	120.00	0.00	51.16	88.24	51.16	10.80	14.69	3.95
05992F	bi-fuel	1690.00	20.00	0.00	14.11	0.00	20.00	14.11	84.50	84.50	0.83
05994F	bi-fuel	1722.00	129.00	0.00	90.98	0.00	129.00	90.98	13.35	13.35	5.28
05995F	bi-fuel	718.00	44.00	0.00	31.03	0.00	44.00	31.03	16.32	16.32	4.32
05996F	bi-fuel	1296.00	90.20	35.50	63.62	15.13	116.30	78.75	10.31	11.14	6.08
05997F	bi-fuel	1599.00	0.00	195.90	0.00	83.51	144.04	83.51	8.16	11.10	5.22
UT	gasoline	1129.00	72.59		51.20		72.59	51.20	15.55	15.55	4.53

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

September-98											
TxDOT Eqpt. No.	type	miles this mo.	gasoline used (gallons)	LPG used (act. gallons)	gasoline cost (\$)	LPG cost (\$)	tot. equiv gallons	total fuel cost (\$)	mi/act. gallon	MPEGG	FOC (cents/mile)
03556G	bi-fuel	2472.00	13.00	258.20	8.61	143.53	202.85	152.15	9.12	12.19	6.15
03558G	bi-fuel										
03562G	bi-fuel										
03563G	bi-fuel	3498.00	40.00	284.20	26.50	157.99	248.97	184.49	10.79	14.05	5.27
03570G	bi-fuel	1880.00	118.60		78.57	0.00	118.60	78.57	15.85	15.85	4.18
03574G	bi-fuel	2834.00	101.70	124.60	67.38	69.27	193.32	136.64	12.52	14.66	4.82
03575G	bi-fuel	1378.00	99.00	15.00	65.59	8.34	110.03	73.93	12.09	12.52	5.36
03577G	bi-fuel	1261.00	49.00	82.00	32.46	45.58	109.29	78.05	9.63	11.54	6.19
03578G	bi-fuel										
03579G	bi-fuel	1387.00	92.10		61.02	0.00	92.10	61.02	15.06	15.06	4.40
03625G	bi-fuel										
03626G	bi-fuel										
04355G	gasoline										
05414F	bi-fuel										
05415F	bi-fuel	2426.00	202.00		133.83	0.00	202.00	133.83	12.01	12.01	5.52
05418F	bi-fuel										
05419F	bi-fuel	522.00		36.60	0.00	20.35	26.91	20.35	14.26	19.40	3.90
03644G	bi-fuel	724.00	22.00	24.00	14.58	10.41	39.65	24.98	15.74	18.26	3.45
03649G	bi-fuel	685.00	16.00	87.00	10.60	37.72	79.97	48.32	6.65	8.57	7.05
03651G	bi-fuel	917.00	16.00	60.00	10.60	26.02	60.12	36.62	12.07	15.25	3.99
03652G	bi-fuel	1319.00	20.00	63.00	13.25	27.32	66.32	40.57	15.89	19.89	3.08
03655G	bi-fuel										
04353G	gasoline		49.00		32.46		49.00	32.46	0.00		
04354G	gasoline	600.00	35.80		23.72		35.80	23.72	16.76	16.76	3.95
05971F	bi-fuel	250.00	0.00	52.00	0.00	22.55	38.24	22.55	4.81	6.54	9.02
05972F	bi-fuel	410.00	26.20	0.00	17.36	0.00	26.20	17.36	15.65	15.65	4.23
05974F	bi-fuel	1487.00	14.00	134.00	9.28	58.10	112.53	67.38	10.05	13.21	4.53
05975F	bi-fuel	358.00	0.00	83.00	0.00	35.99	61.03	35.99	4.31	5.87	10.05
05976F	bi-fuel	935.00	7.50	134.00	4.97	58.10	106.03	63.07	6.61	8.82	6.75
05992F	bi-fuel	1476.00	26.00	118.00	17.23	51.16	112.76	68.39	10.25	13.09	4.63
05994F	bi-fuel	998.00	82.00	154.00	54.33	66.77	195.24	121.10	4.23	5.11	12.13
05995F	bi-fuel										
05996F	bi-fuel	1058.00	16.00	130.00	10.60	56.37	111.59	66.97	7.25	9.48	6.33
05997F	bi-fuel	1231.30	10.60	174.10	7.02	75.49	138.61	82.51	6.67	8.88	6.70
UT	gasoline	682.00	39.40		26.10		39.40	26.10	17.31	17.31	3.83

Table A.1. Monthly Fuel Use Data from Vehicle Operation Log Forms

overall project period															
TxDOT Eqpt. No.	type	total miles	miles with no log form data	net miles with log form data	tot. gasoline used (gallons)	total LPG used (act. gallons)	total equivalent gallons	tot. gasoline cost (\$)	total LPG cost (\$)	Total fuel costs(\$)	FOC (cents/mile)	%LPG	miles per actual gallon	CFE (mpegg)	CIFE (mpegg)
03556G	bi-fuel	21309.0	6200.0	15109.0	178.70	1811.20	1510.46	145.26	1113.29	1258.56	5.91	91.02	7.59	10.00	12.90
03558G	bi-fuel	22203.0	5449.0	16754.0	104.00	1823.00	1444.44	88.70	1166.98	1255.68	5.66	94.60	8.69	11.60	14.22
03562G	bi-fuel	32785.0	5899.0	26886.0	782.20	1546.20	1919.11	620.67	977.25	1597.92	4.87	66.41	11.55	14.01	14.98
03563G	bi-fuel	13500.0	4177.0	9323.0	65.00	1030.20	822.50	48.07	643.46	691.53	5.12	94.07	8.51	11.33	13.55
03570G	bi-fuel	28186.0	13394.0	14792.0	377.90	1852.90	1740.33	296.77	1210.79	1507.56	5.35	83.06	6.63	8.50	13.18
03574G	bi-fuel	32199.0	2050.0	30149.0	1160.20	852.70	1787.19	935.38	512.47	1447.86	4.50	42.36	14.98	16.87	14.05
03575G	bi-fuel	15590.0	1370.0	14220.0	521.20	1253.90	1140.99	163.08	747.09	910.17	5.84	70.64	8.01	12.46	13.34
03577G	bi-fuel	20828.0	1122.0	19706.0	835.00	1498.90	1937.13	659.10	921.27	1580.38	7.59	64.22	8.44	10.17	9.96
03578G	bi-fuel	11905.0		11905.0	155.00	1094.19	959.55	113.67	665.51	779.19	6.55	87.59	9.53	12.41	9.92
03579G	bi-fuel	8007.0	609.0	7398.0	114.10	605.30	559.17	79.71	385.60	465.31	5.81	84.14	10.28	13.23	14.82
03625G	bi-fuel	1428.0		1428.0	14.00	126.70	107.16	12.11	82.52	94.63	6.63	90.05	10.15	13.33	13.33
03626G	bi-fuel	48056.0	8020.0	40036.0	0.00	4173.00	3068.38	0.00	2586.55	2586.55	5.38	100.00	9.59	13.05	15.55
04355G	gasoline	6833.0		6833.0	437.30		437.30	378.62		378.62	5.54	0.00	15.63	15.63	15.73
05414F	bi-fuel	3328.0	789.0	2539.0	57.00	255.50	244.87	49.12	154.63	203.74	6.12	81.76	8.12	10.37	13.20
05415F	bi-fuel	8093.0		8093.0	350.00	457.00	686.03	244.80	267.64	512.44	6.33	56.63	10.03	11.80	12.39
05418F	bi-fuel	7914.0		7914.0	59.00	811.60	655.76	44.83	528.92	573.74	7.25	93.22	9.09	12.07	10.09
05419F	bi-fuel	25962.7		25962.7	162.60	1782.70	1473.41	123.68	1064.19	1187.87	4.58	91.64	13.35	17.62	14.34
03644G	bi-fuel	13064.0		13064.0	392.20	904.40	1057.20	315.30	451.79	767.09	5.87	69.75	10.08	12.36	10.47
03649G	bi-fuel	14520.0		14520.0	263.20	1172.90	1125.63	206.42	594.98	801.40	5.52	81.67	10.11	12.90	12.88
03651G	bi-fuel	17549.0		17549.0	395.00	1280.60	1336.62	305.99	638.70	944.68	5.38	76.43	10.47	13.13	11.13
03652G	bi-fuel	15043.0		15043.0	194.00	1097.00	1000.62	143.19	555.31	698.50	4.64	84.97	11.65	15.03	12.85
03655G	bi-fuel	5730.0		5730.0	129.00	415.60	434.59	98.54	226.43	324.96	5.67	76.31	10.52	13.18	12.79
04353G	gasoline	20032.0		20032.0	1517.90		1517.90	1211.12		1211.12	6.05	0.00	13.20	13.20	13.45
04354G	gasoline	16212.0		16212.0	1056.40		1056.40	847.48		847.48	5.23	0.00	15.35	15.35	14.35
05971F	bi-fuel	11993.0		11993.0	377.00	1129.50	1207.51	295.52	582.69	878.21	7.32	74.98	7.96	9.93	10.36
05972F	bi-fuel	6016.0	1437.0	4579.0	215.20	181.20	348.44	171.06	94.34	265.40	4.41	45.71	11.55	13.14	15.86
05974F	bi-fuel	23503.0	527.0	22976.0	279.20	1855.00	1643.17	219.84	936.59	1156.43	4.92	86.92	10.77	13.98	13.87
05975F	bi-fuel	24068.0	877.0	23191.0	541.00	1911.00	1946.15	455.43	946.09	1401.51	5.82	77.94	9.46	11.92	11.70
05976F	bi-fuel	16501.0	911.0	15590.0	232.70	1475.20	1317.41	196.11	747.00	943.11	5.72	86.38	9.13	11.83	12.37
05992F	bi-fuel	23350.0	1912.0	21438.0	231.00	2093.30	1770.19	183.78	1081.23	1265.01	5.42	90.06	9.22	12.11	11.88
05994F	bi-fuel	20781.0		20781.0	440.80	1813.80	1774.48	332.95	918.21	1251.15	6.02	80.45	9.22	11.71	11.99
05995F	bi-fuel	20337.0	607.0	19730.0	161.00	1976.40	1614.24	125.50	1024.55	1150.05	5.65	92.47	9.23	12.22	12.72
05996F	bi-fuel	18794.0	445.0	18349.0	234.80	1602.60	1413.18	182.10	821.77	1003.87	5.34	87.22	9.99	12.98	12.17
05997F	bi-fuel	21963.3	1035.0	20928.3	407.90	1779.00	1715.99	331.59	901.53	1233.12	5.61	81.35	9.57	12.20	12.54
UT	gasoline	32317.4		32317.4	2191.87		2191.87	1730.55		1730.55	5.35	0.00	14.74	14.74	14.95

Table A.2. Monthly Fuel Use Data from the TxDOT Database

June-97									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	827	0	0.00	178	127.38	115.93	6.32	4.65
03558G	bi-fuel	2421	20	16.79	196	131.75	127.65	14.75	11.21
03562G	bi-fuel	2011	0	0.00	138	95.28	89.88	19.82	14.57
03563G	bi-fuel	870	7	6.05	156	112.29	101.60	7.15	5.34
03570G	bi-fuel	527	16	13.91	0	0.00	0.00	32.94	32.94
03574G	bi-fuel	1113	157	134.88	0	0.00	0.00	7.09	7.09
03575G	bi-fuel	535	0	0.00	0	0.00	0.00		
03577G	bi-fuel	661	42	35.18	43	32.68	28.01	8.98	7.78
03578G	bi-fuel	0	20	17.41	47	29.09	30.61	0.00	0.00
03579G	bi-fuel	1129	31	27.81	127	88.78	82.72	9.08	7.15
03625G	bi-fuel	2420	58	50.66	216	111.37	140.68	11.16	8.83
03626G	bi-fuel	2252	5	4.38	0	0.00	0.00	450.40	450.40
04355G	gasoline	2327	108	93.38	0	0.00	0.00	21.55	21.55
05414F	bi-fuel	0	12	10.37	72	48.05	46.89	0.00	0.00
05415F	bi-fuel	1627	82	69.93	97	74.28	63.18	10.61	9.09
05418F	bi-fuel	536	10	8.38	105	164.84	68.39	6.15	4.66
05419F	bi-fuel	2145	71	61.79	0	168.00	0.00	30.21	30.21
Houston District									
03644G	bi-fuel	1052	24	21.11	53	29.12	28.04	16.71	13.66
03649G	bi-fuel	368	0	0.00	76	41.76	40.20	6.59	4.84
03651G	bi-fuel	602	17	14.99	90	53.86	47.61	7.24	5.63
03652G	bi-fuel	482	0	0.00	72	39.71	38.09	9.10	6.69
03655G	bi-fuel	562	0	0.00	18	9.85	9.52	42.46	31.22
04353G	gasoline	1003	72	62.84	0	0.00	0.00	13.93	13.93
04354G	gasoline	772	70	60.53	0	0.00	0.00	11.03	11.03
05971F	bi-fuel	139	0	0.00	21	11.61	11.11	9.00	6.62
05972F	bi-fuel	355	11	9.55	21	11.49	11.11	13.43	11.09
05974F	bi-fuel	1023	0	0.00	123	67.57	65.07	11.31	8.32
05975F	bi-fuel	897	0	0.00	93	51.23	49.20	13.12	9.65
05976F	bi-fuel	609	8	6.90	66	36.06	34.91	10.77	8.23
05992F	bi-fuel	893	18	15.62	125	72.98	66.13	8.12	6.24
05994F	bi-fuel	1360	0	0.00	117	64.39	61.89	15.81	11.62
05995F	bi-fuel	1152	11	9.48	160	88.15	84.64	8.95	6.74
05996F	bi-fuel	315	10	8.62	43	23.59	22.75	7.57	5.94
05997F	bi-fuel	1481	13	11.21	155	85.13	82.00	11.66	8.82

Table A.2. Monthly Fuel Use Data from the TxDOT Database

July-97									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	1311	17	14.24	307	232.26	201.30	5.40	4.05
03558G	bi-fuel	3060	50	41.95	224	150.53	146.88	14.25	11.17
03562G	bi-fuel	3214	116	100.52	115	77.71	75.41	16.03	13.91
03563G	bi-fuel	94	0	0.00	75	49.37	49.18	1.70	1.25
03570G	bi-fuel	1376	104	91.41	251	176.03	164.58	4.77	3.88
03574G	bi-fuel	2146	207	174.35	0	0.00	0.00	10.37	10.37
03575G	bi-fuel	354	11	8.99	73	38.08	47.87	5.47	4.21
03577G	bi-fuel	2184	87	72.88	288	227.26	188.84	7.31	5.82
03578G	bi-fuel	2101	58	48.77	139	85.43	91.14	13.11	10.66
03579G	bi-fuel	2534	14	12.62	142	94.83	93.11	21.40	16.24
03625G	bi-fuel	2286	241	202.20	126	65.37	82.62	6.85	6.23
03626G	bi-fuel	2920	33	28.24	540	434.84	354.08	6.79	5.10
04355G	gasoline	3081	249	203.44	0	0.00	0.00	12.37	12.37
05414F	bi-fuel	1959	27	22.80	116	208.17	76.06	17.45	13.70
05415F	bi-fuel	3037	168	141.46	250	358.57	163.93	8.63	7.27
05418F	bi-fuel	1090	19	15.92	191	155.38	125.24	6.84	5.19
05419F	bi-fuel	2966	157	132.18	79	48.03	51.80	13.79	12.57
Houston District									
03644G	bi-fuel	971	39	34.05	45	24.32	24.00	13.47	11.56
03649G	bi-fuel	1382	4	3.49	107	57.82	57.07	16.72	12.45
03651G	bi-fuel	1459	26	22.88	141	76.12	75.21	11.25	8.74
03652G	bi-fuel	1119	9	7.92	138	74.53	73.61	10.13	7.61
03655G	bi-fuel	296	8	7.04	34	18.35	18.14	8.97	7.05
04353G	gasoline	1847	125	108.93	0	0.00	0.00	14.78	14.78
04354G	gasoline	1156	88	77.49	0	0.00	0.00	13.14	13.14
05971F	bi-fuel	1111	9	7.92	115	62.32	61.34	11.87	8.96
05972F	bi-fuel	682	43	37.70	20	10.81	10.67	11.82	10.83
05974F	bi-fuel	616	13	11.45	156	84.21	83.21	4.82	3.64
05975F	bi-fuel	1777	15	13.10	220	118.90	117.35	10.05	7.56
05976F	bi-fuel	2431	40	34.69	220	122.63	117.35	12.05	9.35
05992F	bi-fuel	1755	29	25.53	216	116.65	115.21	9.34	7.16
05994F	bi-fuel	1324	10	8.73	151	81.61	80.54	10.94	8.22
05995F	bi-fuel	1183	5	4.34	186	100.41	99.21	8.34	6.19
05996F	bi-fuel	961	0	0.00	131	70.77	69.88	9.98	7.34
05997F	bi-fuel	2470	3	2.62	259	140.01	138.15	12.77	9.43

Table A.2. Monthly Fuel Use Data from the TxDOT Database

August-97									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	639	50	42.16	0	0.00	0.00	12.78	12.78
03558G	bi-fuel	0	0	0.00	299	200.10	202.30	0.00	0.00
03562G	bi-fuel	1414	92	78.63	169	114.60	114.35	6.54	5.42
03563G	bi-fuel	533	1	0.81	25	16.34	16.92	27.50	20.50
03570G	bi-fuel	2115	91	79.83	220	146.34	148.85	8.37	6.80
03574G	bi-fuel	2308	107	87.58	0	0.00	0.00	21.57	21.57
03575G	bi-fuel	0	46	39.10	0	0.00	0.00	0.00	0.00
03577G	bi-fuel	1377	97	81.80	0	0.00	0.00	14.20	14.20
03578G	bi-fuel	2194	13	11.39	106	67.26	71.72	24.13	18.44
03579G	bi-fuel	2077	0	0.00	310	210.75	209.75	9.11	6.70
03625G	bi-fuel	1776	88	75.53	0	0.00	0.00	20.18	20.18
03626G	bi-fuel	2470	24	20.48	250	199.22	169.15	11.89	9.01
04355G	gasoline	2458	138	122.08	0	0.00	0.00	17.81	17.81
05414F	bi-fuel	828	15	14.01	103	68.62	69.69	9.13	7.02
05415F	bi-fuel	1660	97	81.96	0	0.00	0.00	17.11	17.11
05418F	bi-fuel	605	20	16.87	0	0.00	0.00	30.25	30.25
05419F	bi-fuel	2028	75	65.72	196	119.27	132.61	9.26	7.48
Houston District									
03644G	bi-fuel	166	16	15.45	47	109.99	26.05	3.28	2.63
03649G	bi-fuel	378	0	0.00	37	145.98	20.51	13.89	10.22
03651G	bi-fuel	23	18	16.45	83	128.83	46.01	0.29	0.23
03652G	bi-fuel	383	14	12.72	81	43.74	44.90	5.21	4.03
03655G	bi-fuel	49	8	6.61	37	145.98	20.51	1.39	1.09
04353G	gasoline	628	68	61.50	0	0.00	0.00	9.24	9.24
04354G	gasoline	82	97	88.69	0	0.00	0.00	0.85	0.85
05971F	bi-fuel	0	28	25.45	143	203.23	79.26	0.00	0.00
05972F	bi-fuel	0	38	34.72	21	137.34	11.64	0.00	0.00
05974F	bi-fuel	811	18	16.35	79	42.67	43.79	10.66	8.36
05975F	bi-fuel	1178	31	27.06	143	246.35	79.26	8.65	6.77
05976F	bi-fuel	956	43	39.04	88	216.07	48.78	8.88	7.30
05992F	bi-fuel	1588	23	20.91	129	69.66	71.50	13.47	10.45
05994F	bi-fuel	394	15	13.10	76	41.67	42.13	5.56	4.33
05995F	bi-fuel	674	14	11.57	58	31.32	32.15	11.90	9.36
05996F	bi-fuel	1096	45	39.94	131	71.97	72.61	7.76	6.23
05997F	bi-fuel	506	47	40.57	55	29.95	30.49	5.79	4.96

Table A.2. Monthly Fuel Use Data from the TxDOT Database

September-97									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	1536	71	59.87	40	30.40	27.76	15.30	13.84
03558G	bi-fuel	0	0	0.00	0	0.00	0.00		
03562G	bi-fuel	3948	12	10.12	188	132.21	130.47	26.28	19.74
03563G	bi-fuel	1105	2	1.63	92	60.90	63.85	15.87	11.76
03570G	bi-fuel	4487	11	9.85	258	178.05	179.05	22.36	16.68
03574G	bi-fuel	115	111	92.00	0	0.00	0.00	1.04	1.04
03575G	bi-fuel	884	17	15.54	33	22.86	22.90	21.42	17.68
03577G	bi-fuel	1500	70	59.03	205	156.25	142.27	6.80	5.45
03578G	bi-fuel	0	13	11.39	137	87.04	95.08	0.00	0.00
03579G	bi-fuel	327	23	20.37	0	0.00	0.00	14.22	14.22
03625G	bi-fuel	2831	142	129.21	34	22.74	23.60	16.95	16.09
03626G	bi-fuel	4716	41	35.10	280	227.41	194.32	19.10	14.69
04355G	gasoline	3284	144	127.74	0	0.00	0.00	22.81	22.81
05414F	bi-fuel	1531	21	17.11	67	45.28	46.50	21.79	17.40
05415F	bi-fuel	1727	73	61.47	88	67.80	61.07	12.54	10.73
05418F	bi-fuel	0	16	13.49	65	46.35	45.11	0.00	0.00
05419F	bi-fuel	2576	88	77.37	76	47.85	52.74	17.90	15.71
Houston District									
03644G	bi-fuel	953	22	21.00	25	14.30	14.29	23.60	20.28
03649G	bi-fuel	235	74	70.72	13	7.43	7.43	2.81	2.70
03651G	bi-fuel	851	6	5.38	10	5.55	5.72	63.73	53.19
03652G	bi-fuel	1657	0	0.00	14	8.08	8.00	160.97	118.36
03655G	bi-fuel	1330	10	9.25	53	30.24	30.30	27.16	21.11
04353G	gasoline	1055	89	85.00	0	0.00	0.00	11.85	11.85
04354G	gasoline	1727	17	15.73	0	0.00	0.00	101.59	101.59
05971F	bi-fuel	2790	27	24.98	87	48.26	49.74	30.67	24.47
05972F	bi-fuel	1229	34	31.46	22	12.69	12.58	24.49	21.95
05974F	bi-fuel	2731	9	8.33	153	86.68	87.47	22.48	16.86
05975F	bi-fuel	2119	111	105.58	53	30.30	30.30	14.13	12.92
05976F	bi-fuel	1817	89	84.79	67	38.31	38.30	13.14	11.65
05992F	bi-fuel	2358	0	0.00	212	119.24	121.20	15.13	11.12
05994F	bi-fuel	969	73	69.45	0	0.00	0.00	13.27	13.27
05995F	bi-fuel	1643	7	6.48	145	81.44	82.90	14.46	10.81
05996F	bi-fuel	1526	58	55.17	33	18.87	18.87	18.55	16.77
05997F	bi-fuel	2351	114	108.46	59	33.74	33.73	14.94	13.59

Table A.2. Monthly Fuel Use Data from the TxDOT Database

October-97									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	2249	0	0.00	92	197.89	64.92	33.25	24.45
03558G	bi-fuel	3910	109	89.66	33	23.24	23.28	29.34	27.54
03562G	bi-fuel	969	87	76.87	195	308.55	137.59	4.21	3.44
03563G	bi-fuel	590	36	32.78	118	84.31	83.26	4.81	3.83
03570G	bi-fuel	3557	42	37.15	157	287.58	110.78	22.59	17.87
03574G	bi-fuel	2163	15	12.04	34	191.97	23.99	54.08	44.14
03575G	bi-fuel	0	3	2.71	35	144.91	24.70	0.00	0.00
03577G	bi-fuel	2517	0	0.00	154	111.61	108.66	22.23	16.34
03578G	bi-fuel	1855	3	2.56	67	45.57	47.28	35.49	26.50
03579G	bi-fuel	1092	42	36.09	27	19.18	19.05	17.65	15.83
03625G	bi-fuel	2484	17	15.33	118	64.42	83.26	23.94	18.40
03626G	bi-fuel	4387	32	28.67	383	487.73	270.24	13.99	10.57
04355G	gasoline	2207	120	105.18	0	0.00	0.00	18.39	18.39
05414F	bi-fuel	1455	30	26.86	162	113.13	114.31	9.76	7.58
05415F	bi-fuel	2016	59	49.68	168	131.24	118.54	11.04	8.88
05418F	bi-fuel	1730	0	0.00	141	107.96	99.49	16.69	12.27
05419F	bi-fuel	2136	105	90.32	78	50.48	55.04	13.16	11.67
Houston District									
03644G	bi-fuel	859	37	33.23	48	28.63	28.00	11.88	10.11
03649G	bi-fuel	1856	5	4.26	96	56.53	56.00	24.55	18.38
03651G	bi-fuel	1212	69	62.85	102	59.47	59.50	8.42	7.09
03652G	bi-fuel	961	20	18.22	92	53.47	53.66	10.96	8.58
03655G	bi-fuel	636	12	10.93	119	69.44	69.41	6.39	4.85
04353G	gasoline	1268	86	73.15	0	0.00	0.00	14.74	14.74
04354G	gasoline	806	96	86.70	0	0.00	0.00	8.40	8.40
05971F	bi-fuel	84	24	21.85	41	23.78	23.92	1.55	1.29
05972F	bi-fuel	332	12	10.93	14	8.33	8.17	14.89	12.77
05974F	bi-fuel	1960	61	55.56	127	74.32	74.08	12.70	10.43
05975F	bi-fuel	1952	131	111.46	0	0.00	0.00	14.90	14.90
05976F	bi-fuel	796	21	17.83	77	45.67	44.91	10.26	8.12
05992F	bi-fuel	1673	63	57.38	160	93.53	93.33	9.26	7.50
05994F	bi-fuel	1457	0	0.00	145	85.25	84.58	13.67	10.05
05995F	bi-fuel	1351	23	20.95	147	85.79	85.75	10.31	7.95
05996F	bi-fuel	1900	20	17.04	129	76.43	75.25	16.54	12.75
05997F	bi-fuel	1368	28	23.87	120	71.52	70.00	11.77	9.24

Table A.2. Monthly Fuel Use Data from the TxDOT Database

November-97									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	1330	10	7.99	298	238.79	198.94	5.80	4.32
03558G	bi-fuel	2531	32	25.51	0	168.00	0.00	79.09	79.09
03562G	bi-fuel	1580	36	31.81	59	43.04	39.39	19.90	16.63
03563G	bi-fuel	0	11	10.01	0	126.00	0.00	0.00	0.00
03570G	bi-fuel	2949	59	50.29	323	263.51	215.63	9.95	7.72
03574G	bi-fuel	1744	30	24.54	73	52.17	48.73	20.84	16.93
03575G	bi-fuel	646	6	5.01	0	0.00	0.00	107.67	107.67
03577G	bi-fuel	0	0	0.00	40	199.60	26.70	0.00	0.00
03578G	bi-fuel	568	0	0.00	90	228.61	60.08	8.58	6.31
03579G	bi-fuel	4370	9	7.41	392	442.92	261.70	14.70	10.90
03625G	bi-fuel	1771	8	6.67	0	168.00	0.00	221.38	221.38
03626G	bi-fuel	1856	0	0.00	409	349.66	273.05	6.17	4.54
04355G	gasoline	2032	136	113.47	0	0.00	0.00	14.94	14.94
05414F	bi-fuel	323	5	4.02	0	0.00	0.00	64.60	64.60
05415F	bi-fuel	965	0	0.00	156	126.77	104.15	8.41	6.19
05418F	bi-fuel	0	17	13.59	69	56.39	46.06	0.00	0.00
05419F	bi-fuel	2118	10	8.54	141	94.63	94.13	18.63	14.03
Houston District									
03644G	bi-fuel	817	32	28.77	72	42.41	39.26	9.62	7.86
03649G	bi-fuel	453	23	19.61	56	32.99	30.54	7.06	5.73
03651G	bi-fuel	315	0	0.00	20	11.90	10.91	21.42	15.75
03652G	bi-fuel	368	0	0.00	0	0.00	0.00		
03655G	bi-fuel	573	0	0.00	15	8.92	8.18	51.95	38.20
04353G	gasoline	719	46	38.94	0	0.00	0.00	15.63	15.63
04354G	gasoline	1203	8	7.00	0	0.00	0.00	150.38	150.38
05971F	bi-fuel	1168	10	8.74	40	23.80	21.81	29.64	23.36
05972F	bi-fuel	0	0	0.00	0	0.00	0.00		
05974F	bi-fuel	1118	0	0.00	23	13.68	12.54	66.11	48.61
05975F	bi-fuel	1219	0	0.00	172	101.13	93.79	9.64	7.09
05976F	bi-fuel	887	9	7.62	54	31.65	29.45	18.21	14.08
05992F	bi-fuel	1770	0	0.00	36	21.42	19.63	66.87	49.17
05994F	bi-fuel	302	12	10.16	118	69.24	64.35	3.06	2.32
05995F	bi-fuel	1576	0	0.00	40	23.79	21.81	53.58	39.40
05996F	bi-fuel	1539	16	13.54	161	94.67	87.79	11.45	8.69
05997F	bi-fuel	1720	20	16.91	166	97.27	90.52	12.11	9.25

Table A.2. Monthly Fuel Use Data from the TxDOT Database

December-97									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	1026	0	0.00	95	76.05	61.12	14.69	10.80
03558G	bi-fuel	2983	77	61.04	463	333.09	297.89	7.15	5.52
03562G	bi-fuel	3678	16	14.14	110	80.33	70.77	37.96	29.19
03563G	bi-fuel	3124	4	3.61	170	128.28	109.38	24.22	17.95
03570G	bi-fuel	3138	37	30.31	301	237.02	193.66	12.15	9.28
03574G	bi-fuel	0	112	90.00	41	30.43	26.38	0.00	0.00
03575G	bi-fuel	545	0	0.00	137	76.02	88.15	5.41	3.98
03577G	bi-fuel	630	0	0.00	0	0.00	0.00		
03578G	bi-fuel	333	20	16.38	35	22.62	22.52	7.28	6.05
03579G	bi-fuel	1739	32	27.07	58	46.98	37.32	23.30	19.32
03625G	bi-fuel	2343	2	1.62	432	240.08	277.95	7.33	5.40
03626G	bi-fuel	2915	6	4.92	181	135.75	116.46	20.96	15.59
04355G	gasoline	2615	141	114.49	0	0.00	0.00	18.55	18.55
05414F	bi-fuel	1106	14	11.25	76	54.33	48.90	15.83	12.29
05415F	bi-fuel	1008	18	14.67	0	0.00	0.00	56.00	56.00
05418F	bi-fuel	0	6	4.79	108	83.62	69.49	0.00	0.00
05419F	bi-fuel	0	30	24.60	158	105.88	101.66	0.00	0.00
Houston District									
03644G	bi-fuel	1036	23	19.44	68	37.75	35.43	14.19	11.38
03649G	bi-fuel	851	0	0.00	107	59.08	55.76	10.82	7.95
03651G	bi-fuel	1063	52	44.76	145	85.34	75.56	6.70	5.40
03652G	bi-fuel	0	0	0.00	33	19.41	17.20	0.00	0.00
03655G	bi-fuel	124	0	0.00	22	13.14	11.46	7.67	5.64
04353G	gasoline	1087	82	69.05	0	0.00	0.00	13.26	13.26
04354G	gasoline	597	124	105.77	0	0.00	0.00	4.81	4.81
05971F	bi-fuel	1023	15	12.74	77	45.23	40.12	14.28	11.12
05972F	bi-fuel	381	23	19.64	21	12.54	10.94	9.91	8.66
05974F	bi-fuel	1610	28	23.65	130	76.53	67.74	13.03	10.19
05975F	bi-fuel	1841	0	0.00	207	114.06	107.87	12.10	8.89
05976F	bi-fuel	37	0	0.00	27	15.60	14.07	1.86	1.37
05992F	bi-fuel	1121	32	26.73	235	138.69	122.46	5.47	4.20
05994F	bi-fuel	1657	11	9.15	121	66.70	63.05	16.57	12.55
05995F	bi-fuel	1600	16	13.68	202	119.24	105.26	9.72	7.34
05996F	bi-fuel	1564	0	0.00	173	95.65	90.15	12.30	9.04
05997F	bi-fuel	648	5	4.23	66	37.06	34.39	12.11	9.13

Table A.2. Monthly Fuel Use Data from the TxDOT Database

January-98									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	1808	0	0.00	192	134.39	117.04	12.81	9.42
03558G	bi-fuel	2677	19	14.74	242	165.27	147.52	13.59	10.26
03562G	bi-fuel	1950	91	80.40	206	143.52	125.58	8.04	6.57
03563G	bi-fuel	1006	24	21.63	73	52.14	44.50	12.95	10.37
03570G	bi-fuel	1973	10	7.97	121	84.81	73.76	19.94	15.06
03574G	bi-fuel	3748	0	0.00	26	17.54	15.85	196.05	144.15
03575G	bi-fuel	1269	0	0.00	136	70.54	82.91	12.69	9.33
03577G	bi-fuel	494	30	23.47	104	71.15	63.40	4.64	3.69
03578G	bi-fuel	793	0	0.00	69	43.62	42.06	15.63	11.49
03579G	bi-fuel	1088	27	21.54	181	133.39	110.34	6.80	5.23
03625G	bi-fuel	2281	11	8.74	183	100.41	111.56	15.67	11.76
03626G	bi-fuel	4385	0	0.00	268	216.81	163.37	22.25	16.36
04355G	gasoline	1533	246	192.66	0	0.00	0.00	6.23	6.23
05414F	bi-fuel	901	10	7.66	68	46.49	41.45	15.02	11.55
05415F	bi-fuel	1779	104	84.78	124	98.03	75.59	9.11	7.80
05418F	bi-fuel	981	9	7.06	72	55.47	43.89	15.84	12.11
05419F	bi-fuel	1420	21	17.18	0	0.00	0.00	67.62	67.62
Houston District									
03644G	bi-fuel	1341	36	29.78	105	57.08	51.17	11.85	9.51
03649G	bi-fuel	1031	10	8.25	64	34.47	31.19	18.07	13.93
03651G	bi-fuel	484	19	15.51	63	34.98	30.70	7.41	5.90
03652G	bi-fuel	363	8	6.53	111	61.64	54.09	4.05	3.05
03655G	bi-fuel	167	0	0.00	42	23.32	20.47	5.41	3.98
04353G	gasoline	1546	105	86.74	0	0.00	0.00	14.72	14.72
04354G	gasoline	865	71	57.93	0	0.00	0.00	12.18	12.18
05971F	bi-fuel	0	13	10.61	41	22.77	19.98	0.00	0.00
05972F	bi-fuel	350	13	10.61	22	12.22	10.72	12.00	10.00
05974F	bi-fuel	380	0	0.00	234	129.97	114.03	2.21	1.62
05975F	bi-fuel	1789	0	0.00	165	90.10	80.40	14.75	10.84
05976F	bi-fuel	1099	24	18.84	83	44.23	40.45	12.92	10.27
05992F	bi-fuel	912	6	4.90	143	79.42	69.68	8.21	6.12
05994F	bi-fuel	1577	12	9.90	117	63.66	57.01	16.09	12.22
05995F	bi-fuel	1805	36	29.38	269	149.42	131.08	7.72	5.92
05996F	bi-fuel	1612	22	18.15	125	67.73	60.91	14.15	10.97
05997F	bi-fuel	748	0	0.00	72	38.67	35.09	14.13	10.39

Table A.2. Monthly Fuel Use Data from the TxDOT Database

February-98									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	1897	47	36.87	96	70.56	58.09	16.13	13.27
03558G	bi-fuel	3161	22	16.06	221	146.93	133.73	17.13	13.01
03562G	bi-fuel	2416	28	24.74	0	0.00	0.00	86.29	86.29
03563G	bi-fuel	840	5	4.38	124	86.38	75.03	8.73	6.51
03570G	bi-fuel	1690	28	21.72	0	0.00	0.00	60.36	60.36
03574G	bi-fuel	2083	109	86.85	38	24.46	22.99	15.21	14.17
03575G	bi-fuel	954	0	0.00	147	76.55	88.95	8.83	6.49
03577G	bi-fuel	1585	33	25.89	81	60.36	49.01	17.12	13.90
03578G	bi-fuel	743	0	0.00	73	44.10	44.17	13.84	10.18
03579G	bi-fuel	2030	6	4.62	116	75.25	70.19	22.24	16.64
03625G	bi-fuel	2084	0	0.00	190	94.40	114.97	14.92	10.97
03626G	bi-fuel	4327	6	4.78	317	252.70	191.82	18.10	13.40
04355G	gasoline	2630	0	0.00	0	0.00	0.00		
05414F	bi-fuel	553	0	0.00	62	40.12	37.52	12.13	8.92
05415F	bi-fuel	1812	57	42.15	81	58.75	49.01	15.55	13.13
05418F	bi-fuel	1504	0	0.00	66	46.85	39.94	30.99	22.79
05419F	bi-fuel	2631	0	0.00	112	63.96	67.77	31.95	23.49
Houston District									
03644G	bi-fuel	598	0	0.00	88	44.73	42.49	9.24	6.80
03649G	bi-fuel	483	0	0.00	52	26.09	25.11	12.63	9.29
03651G	bi-fuel	654	6	4.90	42	22.58	20.28	17.73	13.63
03652G	bi-fuel	1171	0	0.00	54	28.72	26.07	29.49	21.69
03655G	bi-fuel	132	0	0.00	0	0.00	0.00		
04353G	gasoline	1096	122	95.36	0	0.00	0.00	8.98	8.98
04354G	gasoline	1126	25	20.40	0	0.00	0.00	45.04	45.04
05971F	bi-fuel	420	0	0.00	0	0.00	0.00		
05972F	bi-fuel	465	15	12.24	0	0.00	0.00	31.00	31.00
05974F	bi-fuel	1554	0	0.00	24	12.48	11.59	88.06	64.75
05975F	bi-fuel	1762	4	3.09	177	89.12	85.46	13.13	9.73
05976F	bi-fuel	1173	12	9.02	115	57.73	55.52	12.15	9.24
05992F	bi-fuel	1180	0	0.00	65	34.58	31.38	24.69	18.15
05994F	bi-fuel	552	14	10.84	134	67.33	64.70	4.91	3.73
05995F	bi-fuel	1669	0	0.00	92	48.98	44.42	24.67	18.14
05996F	bi-fuel	1270	0	0.00	130	65.24	62.76	13.29	9.77
05997F	bi-fuel	481	0	0.00	48	24.67	23.17	13.63	10.02

Table A.2. Monthly Fuel Use Data from the TxDOT Database

March-98									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	1802	0	0.00	221	157.79	128.64	11.09	8.15
03558G	bi-fuel	1254	16	11.68	445	281.05	259.03	3.65	2.72
03562G	bi-fuel	1406	86	75.98	105	67.31	61.12	8.61	7.36
03563G	bi-fuel	1006	5	4.29	120	80.98	69.85	10.79	8.05
03570G	bi-fuel	0	0	0.00	252	171.62	146.69	0.00	0.00
03574G	bi-fuel	1823	66	51.55	100	62.50	58.21	13.07	10.98
03575G	bi-fuel	1212	18	13.76	90	43.01	52.39	14.40	11.22
03577G	bi-fuel	1127	50	39.22	40	28.40	23.28	14.19	12.52
03578G	bi-fuel	785	14	10.35	92	53.11	53.55	9.61	7.41
03579G	bi-fuel	1470	9	6.80	134	88.00	78.00	13.67	10.28
03625G	bi-fuel	2583	24	17.97	229	107.46	133.30	13.43	10.21
03626G	bi-fuel	4516	19	14.15	380	289.02	221.20	15.13	11.32
04355G	gasoline	3538	360	270.00	0	0.00	0.00	9.83	9.83
05414F	bi-fuel	1887	29	22.65	103	64.62	59.96	18.02	14.30
05415F	bi-fuel	1302	35	25.88	120	86.31	69.85	10.57	8.40
05418F	bi-fuel	0	5	3.92	32	22.72	18.63	0.00	0.00
05419F	bi-fuel	2352	45	33.26	144	83.79	83.82	15.59	12.44
Houston District									
03644G	bi-fuel	684	17	12.60	79	38.38	36.32	9.11	7.13
03649G	bi-fuel	549	7	5.41	95	47.06	43.68	7.14	5.38
03651G	bi-fuel	899	18	13.82	65	33.12	29.89	13.66	10.83
03652G	bi-fuel	926	0	0.00	85	43.33	39.08	14.82	10.89
03655G	bi-fuel	220	20	15.17	42	21.39	19.31	4.32	3.55
04353G	gasoline	841	144	108.96	0	0.00	0.00	5.84	5.84
04354G	gasoline	988	111	84.33	0	0.00	0.00	8.90	8.90
05971F	bi-fuel	407	31	23.43	62	31.55	28.51	5.31	4.38
05972F	bi-fuel	446	39	29.52	43	21.89	19.77	6.32	5.44
05974F	bi-fuel	1544	33	24.55	194	103.34	89.20	8.79	6.80
05975F	bi-fuel	1015	9	6.95	105	52.19	48.28	11.77	8.90
05976F	bi-fuel	1372	0	0.00	150	73.89	68.97	12.44	9.15
05992F	bi-fuel	981	7	5.37	168	85.53	77.25	7.52	5.61
05994F	bi-fuel	1548	8	6.18	140	70.24	64.37	13.95	10.46
05995F	bi-fuel	889	56	42.41	184	93.74	84.60	4.65	3.70
05996F	bi-fuel	1096	0	0.00	87	43.46	40.00	17.13	12.60
05997F	bi-fuel	1602	0	0.00	153	75.92	70.35	14.24	10.47

Table A.2. Monthly Fuel Use Data from the TxDOT Database

April-98									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	2527	38	29.81	78	53.94	46.64	26.50	21.78
03558G	bi-fuel	568	0	0.00	0	0.00	0.00		
03562G	bi-fuel	3811	35	27.34	58	36.21	34.68	49.08	40.98
03563G	bi-fuel	1370	0	0.00	126	76.85	75.35	14.79	10.87
03570G	bi-fuel	5545	5	3.58	0	0.00	0.00	1109.00	1109.00
03574G	bi-fuel	3417	245	191.38	43	25.57	25.71	12.35	11.86
03575G	bi-fuel	2693	14	9.50	130	64.09	77.74	24.57	18.70
03577G	bi-fuel	1123	89	69.81	128	75.72	76.54	6.13	5.18
03578G	bi-fuel	1402	16	11.57	106	57.76	63.39	14.92	11.49
03579G	bi-fuel	1463	27	20.99	126	63.04	75.35	12.23	9.56
03625G	bi-fuel	2919	21	14.26	215	95.93	128.57	16.30	12.37
03626G	bi-fuel	5122	37	26.09	454	331.29	271.49	13.81	10.43
04355G	gasoline	3306	188	128.13	0	0.00	0.00	17.59	17.59
05414F	bi-fuel	1155	66	49.76	102	62.00	61.00	8.19	6.88
05415F	bi-fuel	1760	138	95.24	84	58.30	50.23	8.81	7.93
05418F	bi-fuel	0	0	0.00	0	0.00	0.00		
05419F	bi-fuel	2574	29	20.97	189	104.93	113.02	15.32	11.81
Houston District									
03644G	bi-fuel	1491	26	19.34	26	12.78	12.37	33.05	28.67
03649G	bi-fuel	1432	33	24.54	21	10.32	9.99	29.56	26.52
03651G	bi-fuel	476	26	19.83	124	57.29	58.99	4.06	3.17
03652G	bi-fuel	607	0	0.00	111	51.09	52.80	7.44	5.47
03655G	bi-fuel	274	30	22.73	0	0.00	0.00	9.13	9.13
04353G	gasoline	2877	68	50.57	0	0.00	0.00	42.31	42.31
04354G	gasoline	897	48	36.72	0	0.00	0.00	18.69	18.69
05971F	bi-fuel	887	48	36.51	154	71.15	73.26	5.50	4.39
05972F	bi-fuel	747	25	19.12	23	10.84	10.94	17.82	15.56
05974F	bi-fuel	1062	10	6.80	17	176.01	8.09	47.20	39.33
05975F	bi-fuel	1750	74	55.04	44	21.52	20.93	16.45	14.83
05976F	bi-fuel	1013	46	34.21	40	19.67	19.03	13.43	11.78
05992F	bi-fuel	1428	9	6.89	167	244.74	79.44	10.84	8.11
05994F	bi-fuel	2366	67	49.84	86	167.83	40.91	18.17	15.46
05995F	bi-fuel	1922	43	32.51	203	261.78	96.57	10.00	7.81
05996F	bi-fuel	280	15	10.99	18	8.85	8.56	9.92	8.48
05997F	bi-fuel	2285	124	92.25	90	44.04	42.81	12.02	10.68

Table A.2. Monthly Fuel Use Data from the TxDOT Database

May-98									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	1300	0	0.00	206	142.20	119.83	8.58	6.31
03558G	bi-fuel	921	41	28.81	0	0.00	0.00	22.46	22.46
03562G	bi-fuel	1113	0	0.00	132	81.62	76.78	11.47	8.43
03563G	bi-fuel	96	57	46.26	144	94.22	83.76	0.59	0.48
03570G	bi-fuel	4007	41	29.94	222	148.61	129.14	19.62	15.24
03574G	bi-fuel	0	93	71.88	42	25.08	24.43	0.00	0.00
03575G	bi-fuel	0	5	3.49	89	40.43	51.77	0.00	0.00
03577G	bi-fuel	1334	0	0.00	92	55.58	53.52	19.72	14.50
03578G	bi-fuel	1013	0	0.00	102	56.56	59.33	13.51	9.93
03579G	bi-fuel	1965	72	51.84	39	23.41	22.69	19.52	17.70
03625G	bi-fuel	2060	0	0.00	218	99.74	126.81	12.85	9.45
03626G	bi-fuel	3523	27	19.83	287	213.54	166.95	14.80	11.22
04355G	gasoline	2198	168	117.09	0	0.00	0.00	13.08	13.08
05414F	bi-fuel	1278	0	0.00	71	42.81	41.30	24.48	18.00
05415F	bi-fuel	1186	15	10.54	40	28.17	23.27	26.70	21.56
05418F	bi-fuel	1135	0	0.00	99	62.26	57.59	15.59	11.46
05419F	bi-fuel	2439	0	0.00	225	125.97	130.88	14.74	10.84
Houston District									
03644G	bi-fuel	0	0	0.00	0	0.00	0.00		
03649G	bi-fuel	996	11	8.17	106	51.96	48.70	11.20	8.51
03651G	bi-fuel	1225	14	10.56	81	38.90	37.21	16.65	12.89
03652G	bi-fuel	1381	0	0.00	29	14.09	13.32	64.76	47.62
03655G	bi-fuel	144	31	23.40	0	0.00	0.00	4.65	4.65
04353G	gasoline	1602	119	90.98	0	0.00	0.00	13.46	13.46
04354G	gasoline	1165	54	40.76	0	0.00	0.00	21.57	21.57
05971F	bi-fuel	1834	15	11.32	59	28.86	27.10	31.41	24.78
05972F	bi-fuel	585	29	21.89	0	0.00	0.00	20.17	20.17
05974F	bi-fuel	1556	0	0.00	151	77.16	69.37	14.01	10.30
05975F	bi-fuel	1303	16	12.32	163	79.83	74.88	9.59	7.28
05976F	bi-fuel	865	0	0.00	109	53.32	50.07	10.79	7.94
05992F	bi-fuel	1114	18	13.59	84	40.36	38.59	13.97	10.92
05994F	bi-fuel	656	11	8.47	0	0.00	0.00	59.64	59.64
05995F	bi-fuel	1505	14	10.57	153	74.32	70.29	11.90	9.01
05996F	bi-fuel		1	0.73	60	32.07	27.56	0.00	0.00
05997F	bi-fuel	606	14	10.40	98	48.02	45.02	7.04	5.41

Table A.2. Monthly Fuel Use Data from the TxDOT Database

June-98									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	1763	18	13.35	120	95.77	66.23	16.60	12.78
03558G	bi-fuel	1846	0	0.00	100	69.37	55.19	25.11	18.46
03562G	bi-fuel	2664	253	196.25	80	61.88	44.15	8.54	8.00
03563G	bi-fuel	0	1	0.77	80	55.48	44.15	0.00	0.00
03570G	bi-fuel	267	6	4.39	608	349.49	335.56	0.59	0.43
03574G	bi-fuel	1447	50	37.63	60	40.31	33.11	15.37	13.15
03575G	bi-fuel	1158	27	19.70	100	50.67	55.19	11.52	9.12
03577G	bi-fuel	1216	139	103.12	120	74.66	66.23	5.35	4.69
03578G	bi-fuel	697	0	0.00	90	59.61	49.67	10.53	7.74
03579G	bi-fuel	2299	0	0.00	364	205.96	200.89	8.59	6.32
03625G	bi-fuel	1720	4	2.92	160	85.08	88.30	14.14	10.49
03626G	bi-fuel	3701	29	21.19	360	308.49	198.68	12.60	9.51
04355G	gasoline	1813	140	102.17	0	0.00	0.00	12.95	12.95
05414F	bi-fuel	1786	28	21.58	120	83.30	66.23	15.37	12.07
05415F	bi-fuel	1622	226	159.34	40	28.36	22.08	6.35	6.10
05418F	bi-fuel	325	14	10.39	0	84.00	0.00	23.21	23.21
05419F	bi-fuel	2523	57	43.85	180	288.65	99.34	13.32	10.65
Houston District									
03644G	bi-fuel	244	18	13.78	41	18.69	17.61	5.07	4.14
03649G	bi-fuel	703	0	0.00	59	27.26	25.35	16.20	11.92
03651G	bi-fuel	1340	50	37.80	123	57.99	52.84	9.54	7.75
03652G	bi-fuel	189	36	27.14	62	155.32	26.64	2.32	1.93
03655G	bi-fuel	0	30	22.68	0	0.00	0.00	0.00	0.00
04353G	gasoline	1480	114	87.28	0	0.00	0.00	12.98	12.98
04354G	gasoline	657	98	74.08	0	0.00	0.00	6.70	6.70
05971F	bi-fuel	319	19	14.36	98	46.59	42.10	3.50	2.73
05972F	bi-fuel	628	26	19.65	0	0.00	0.00	24.15	24.15
05974F	bi-fuel	644	18	13.61	212	101.23	91.08	3.70	2.80
05975F	bi-fuel	1837	14	10.72	164	75.98	70.45	13.65	10.32
05976F	bi-fuel	1152	8	6.12	94	43.74	40.38	14.94	11.29
05992F	bi-fuel	793	36	26.70	83	39.96	35.66	8.17	6.66
05994F	bi-fuel	1593	8	6.12	190	88.23	81.62	10.78	8.05
05995F	bi-fuel	1280	9	6.80	155	74.28	66.59	10.41	7.80
05996F	bi-fuel	2036	0	0.00	163	159.26	70.02	16.99	12.49
05997F	bi-fuel	500	44	30.86	36	185.08	15.47	7.10	6.25

Table A.2. Monthly Fuel Use Data from the TxDOT Database

July-98									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	1579	7	5.19	160	124.59	88.50	12.67	9.46
03558G	bi-fuel	1841	27	19.39	130	87.52	71.90	15.02	11.73
03562G	bi-fuel	1324	106	82.62	120	87.04	66.37	6.82	5.86
03563G	bi-fuel	1771	75	57.04	343	181.97	189.71	5.41	4.24
03570G	bi-fuel	316	20	14.25	0	0.00	0.00	15.80	15.80
03574G	bi-fuel	2691	175	129.19	100	67.57	55.31	10.83	9.79
03575G	bi-fuel	2075	0	0.00	150	73.79	82.97	18.81	13.83
03577G	bi-fuel	1473	80	59.35	120	77.44	66.37	8.76	7.37
03578G	bi-fuel	759	36	26.10	80	53.41	44.25	8.00	6.54
03579G	bi-fuel	1819	49	37.30	82	51.37	45.35	16.64	13.89
03625G	bi-fuel	3105	0	0.00	130	59.38	71.90	32.48	23.88
03626G	bi-fuel	4454	54	38.54	290	232.89	160.40	16.67	12.95
04355G	gasoline	3338	23	16.81	0	0.00	0.00	145.13	145.13
05414F	bi-fuel	1045	15	11.48	80	57.24	44.25	14.16	11.00
05415F	bi-fuel	1162	82	49.56	0	0.00	0.00	14.17	14.17
05418F	bi-fuel	1388	23	17.06	70	47.02	38.72	18.64	14.92
05419F	bi-fuel	2783	48	34.75	150	97.66	82.97	17.58	14.06
Houston District									
03644G	bi-fuel	769	0	0.00	91	40.03	39.20	11.49	8.45
03649G	bi-fuel	1371	18	13.44	131	57.59	56.43	11.99	9.20
03651G	bi-fuel	1574	17	12.41	190	87.16	81.85	10.04	7.60
03652G	bi-fuel	949	0	0.00	113	50.33	48.68	11.42	8.40
03655G	bi-fuel	596	0	0.00	54	24.21	23.26	15.01	11.04
04353G	gasoline	1400	94	70.41	0	0.00	0.00	14.89	14.89
04354G	gasoline	1090	61	44.55	0	0.00	0.00	17.87	17.87
05971F	bi-fuel	553	13	9.50	85	37.93	36.62	7.32	5.64
05972F	bi-fuel	418	21	15.33	0	0.00	0.00	19.90	19.90
05974F	bi-fuel	1986	0	0.00	159	70.71	68.50	16.99	12.49
05975F	bi-fuel	783	14	10.05	129	56.64	55.57	7.19	5.48
05976F	bi-fuel	871	6	4.51	125	54.94	53.85	8.90	6.65
05992F	bi-fuel	2207	41	29.21	210	93.45	90.47	11.29	8.79
05994F	bi-fuel	2008	14	10.52	242	112.28	104.25	10.46	7.84
05995F	bi-fuel	888	9	6.80	86	38.67	37.05	12.29	9.35
05996F	bi-fuel	547	0	0.00	101	44.37	43.51	7.37	5.42
05997F	bi-fuel	1796	48	36.03	160	70.32	68.93	10.84	8.63

Table A.2. Monthly Fuel Use Data from the TxDOT Database

August-98									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	0	26	19.29	160	115.53	87.78	0.00	0.00
03558G	bi-fuel	2229	0	0.00	190	126.96	104.23	15.95	11.73
03562G	bi-fuel	1014	31	23.64	60	39.76	32.92	13.50	11.14
03563G	bi-fuel	3330	25	18.71	0	0.00	0.00	133.20	133.20
03570G	bi-fuel	603	13	8.72	40	32.83	21.94	14.22	11.38
03574G	bi-fuel	4916	141	99.14	0	0.00	0.00	34.87	34.87
03575G	bi-fuel	1297	7	4.94	70	31.26	38.40	22.18	16.84
03577G	bi-fuel	4068	79	58.61	30	21.60	16.46	40.25	37.32
03578G	bi-fuel	992	4	2.93	30	16.42	16.46	38.07	29.18
03579G	bi-fuel	1668	10	7.48	193	88.79	105.88	10.98	8.22
03625G	bi-fuel	2377	8	5.34	140	61.15	76.80	21.43	16.06
03626G	bi-fuel	3646	44	30.19	120	91.53	65.83	27.57	22.23
04355G	gasoline	3200	333	230.91	0	0.00	0.00	9.61	9.61
05414F	bi-fuel	1400	0	0.00	60	39.57	32.92	31.73	23.33
05415F	bi-fuel	2414	33	20.67	50	41.40	27.43	34.60	29.08
05418F	bi-fuel	2363	18	13.35	30	23.47	16.46	58.99	49.23
05419F	bi-fuel	2816	77	56.49	30	19.90	16.46	28.43	26.32
Houston District									
03644G	bi-fuel	1158	71	51.89	26	95.49	11.08	12.85	11.94
03649G	bi-fuel	1435	73	53.36	44	145.45	18.76	13.62	12.26
03651G	bi-fuel	2071	124	82.89	74	158.64	31.55	11.61	10.46
03652G	bi-fuel	1407	113	75.39	19	8.38	8.10	11.08	10.66
03655G	bi-fuel	315	30	19.88	0	42.00	0.00	10.50	10.50
04353G	gasoline	1305	76	55.54	0	0.00	0.00	17.17	17.17
04354G	gasoline	916	152	102.74	0	0.00	0.00	6.03	6.03
05971F	bi-fuel	453	111	75.02	39	101.20	16.63	3.24	3.02
05972F	bi-fuel	229	13	9.01	0	84.00	0.00	17.62	17.62
05974F	bi-fuel	2040	88	59.21	44	19.41	18.76	16.95	15.45
05975F	bi-fuel	1688	14	10.23	193	253.31	82.28	10.83	8.15
05976F	bi-fuel	1323	0	0.00	143	189.16	60.96	12.58	9.25
05992F	bi-fuel	1623	148	99.46	70	30.87	29.84	8.14	7.44
05994F	bi-fuel	2394	105	76.53	29	12.82	12.36	18.95	17.87
05995F	bi-fuel	1043	61	41.74	18	7.94	7.67	14.05	13.20
05996F	bi-fuel	1425	16	11.69	161	71.19	68.63	10.60	8.05
05997F	bi-fuel	1980	0	0.00	206	91.04	87.82	13.07	9.61

Table A.2. Monthly Fuel Use Data from the TxDOT Database

September-98									
TxDOT Equipment Number	type	miles this month	gasoline used (gallons)	gasoline cost (\$)	LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	miles per equivalent gallon (mpegg)	miles per actual gallon
Corpus Christi District									
03556G	bi-fuel	2472	0	0.00	150	114.35	83.39	22.41	16.48
03558G	bi-fuel	2560	23	14.34	210	135.14	116.74	14.43	10.99
03562G	bi-fuel	6940	0	0.00	230	182.26	127.86	41.04	30.17
03563G	bi-fuel	0	0	0.00	0	0.00	0.00		
03570G	bi-fuel	1261	178	118.20	150	113.51	83.39	4.37	3.84
03574G	bi-fuel	0	115	77.39	210	132.34	116.74	0.00	0.00
03575G	bi-fuel	1896	95	61.73	190	95.96	105.62	8.08	6.65
03577G	bi-fuel	1291	0	0.00	180	110.50	100.06	9.75	7.17
03578G	bi-fuel	2308	96	61.35	200	115.18	111.18	9.50	7.80
03579G	bi-fuel	3038	105	74.17	80	45.62	44.47	18.54	16.42
03625G	bi-fuel	2761	27	17.55	360	160.25	200.12	9.47	7.13
03626G	bi-fuel	970	0	0.00	470	379.64	261.27	2.81	2.06
04355G	gasoline	1826	113	73.65	0	0.00	0.00	16.16	16.16
05414F	bi-fuel	205	22	14.80	130	173.28	72.27	1.74	1.35
05415F	bi-fuel	3010	221	139.78	230	168.87	127.86	7.72	6.67
05418F	bi-fuel	0	0	0.00	190	141.16	105.62	0.00	0.00
05419F	bi-fuel	1541	19	12.26	360	210.61	200.12	5.43	4.07
Houston District									
03644G	bi-fuel	1445	66	46.23	24	10.58	10.41	17.27	16.06
03649G	bi-fuel	913	46	32.30	82	36.65	35.56	8.59	7.13
03651G	bi-fuel	1386	29	18.57	100	44.16	43.36	13.52	10.74
03652G	bi-fuel	1435	13	8.30	56	24.78	24.28	26.49	20.80
03655G	bi-fuel	258	27	17.24	0	0.00	0.00	9.56	9.56
04353G	gasoline	930	77	54.31	0	0.00	0.00	12.08	12.08
04354G	gasoline	1561	52	33.11	0	0.00	0.00	30.02	30.02
05971F	bi-fuel	590	0	0.00	68	29.91	29.48	11.80	8.68
05972F	bi-fuel	316	42	26.95	0	0.00	0.00	7.52	7.52
05974F	bi-fuel	1384	14	9.07	155	68.30	67.21	10.81	8.19
05975F	bi-fuel	2057	6	4.17	173	76.30	75.01	15.44	11.49
05976F	bi-fuel	1503	8	5.56	160	70.57	69.38	11.96	8.95
05992F	bi-fuel	1621	33	21.15	118	52.22	51.16	13.53	10.74
05994F	bi-fuel	2874	132	93.04	113	50.46	49.00	13.36	11.73
05995F	bi-fuel	769	43	27.81	0	0.00	0.00	17.88	17.88
05996F	bi-fuel	1233	0	0.00	126	55.66	54.63	13.31	9.79
05997F	bi-fuel	1764	33	22.52	162	71.34	70.24	11.60	9.05

Table A.2. Monthly Fuel Use Data from the TxDOT Database

Overall Project Period												
TxDOT Eqpt Number	type	miles during project	total gasoline used (gallons)	gasoline cost (\$)	total LPG used (actual gallons)	TxDOT calc. LPG cost incl. annual tax (\$)	actual LPG purchase cost (\$)	% LPG of all gallons used	miles per equivalent gallon (mpegg)	miles per actual gallon	Fuel Operating Cost (cents/mile)	CIFE excluding outliers (mpegg)
Corpus Christi District												
03556G	bi-fuel	24066	284	228.77	2393	1911.89	1466.11	89.39	11.78	8.99	7.04	12.80
03558G	bi-fuel	31962	436	339.97	2753	2018.95	1686.36	86.33	12.99	10.02	6.34	14.66
03562G	bi-fuel	39452	989	823.06	1965	1551.32	1227.32	66.52	16.21	13.36	5.20	9.17
03563G	bi-fuel	15735	253	207.97	1646	1205.51	1006.55	86.68	10.75	8.29	7.72	14.54
03570G	bi-fuel	33811	661	521.52	2903	2189.40	1803.03	81.45	12.09	9.49	6.88	12.10
03574G	bi-fuel	29714	1733	1360.40	767	669.94	451.47	30.68	12.94	11.89	6.10	11.65
03575G	bi-fuel	15518	249	184.47	1380	828.17	819.54	84.71	12.28	9.53	6.47	12.10
03577G	bi-fuel	22580	796	628.36	1625	1302.81	1009.36	67.12	11.34	9.33	7.25	9.97
03578G	bi-fuel	16543	293	220.20	1463	1065.39	902.50	83.31	12.09	9.42	6.79	12.74
03579G	bi-fuel	30108	456	356.11	2371	1678.27	1456.80	83.87	13.69	10.65	6.02	13.70
03625G	bi-fuel	37801	651	548.00	2751	1535.78	1660.45	80.86	14.14	11.11	5.84	14.07
03626G	bi-fuel	56160	357	276.56	4989	4150.52	3078.31	93.32	13.95	10.51	5.97	14.07
04355G	gasoline	41386	2607	2011.20	0	0.00	0.00	0.00	15.87	15.87	4.86	13.34
05414F	bi-fuel	17412	294	234.35	1392	1147.01	859.23	82.56	13.22	10.33	6.28	14.50
05415F	bi-fuel	28087	1408	1047.11	1528	1326.85	956.18	52.04	11.09	9.57	7.13	11.19
05418F	bi-fuel	11657	157	124.82	1238	1097.49	774.62	88.75	10.92	8.36	7.72	16.69
05419F	bi-fuel	35048	832	679.28	2118	1629.61	1282.37	71.80	14.67	11.88	5.60	14.32
Houston District												
03644G	bi-fuel	13584	427	346.67	838	604.28	415.73	66.25	13.02	10.74	5.61	12.62
03649G	bi-fuel	14436	304	243.55	1146	838.44	562.26	79.03	12.59	9.96	5.58	13.04
03651G	bi-fuel	15634	491	383.60	1453	955.89	707.17	74.74	10.03	8.04	6.98	12.02
03652G	bi-fuel	13398	213	156.22	1070	676.62	528.53	83.40	13.40	10.44	5.11	10.54
03655G	bi-fuel	5676	206	154.93	436	406.84	230.56	67.91	10.78	8.84	6.79	9.54
04353G	gasoline	20684	1487	1199.56	0	0.00	0.00	0.00	13.91	13.91	5.80	14.05
04354G	gasoline	15608	1172	936.53	0	0.00	0.00	0.00	13.32	13.32	6.00	12.12
05971F	bi-fuel	11778	363	282.43	1130	788.19	560.98	75.69	9.87	7.89	7.16	12.65
05972F	bi-fuel	7163	384	308.32	207	322.15	106.54	35.03	13.36	12.12	5.79	13.44
05974F	bi-fuel	22019	292	228.58	1981	1204.27	971.71	87.15	12.59	9.69	5.45	12.34
05975F	bi-fuel	24967	439	369.77	2201	1456.96	1071.04	83.37	12.14	9.46	5.77	13.44
05976F	bi-fuel	17904	314	269.13	1618	1113.24	786.38	83.75	11.91	9.27	5.90	12.17
05992F	bi-fuel	23017	463	353.44	2221	1333.30	1112.94	82.75	10.98	8.58	6.37	12.62
05994F	bi-fuel	23031	492	382.03	1779	1041.71	870.77	78.34	12.79	10.14	5.44	14.67
05995F	bi-fuel	20949	347	264.52	2098	1279.27	1049.99	85.81	11.09	8.57	6.27	10.42
05996F	bi-fuel	18400	203	175.87	1772	999.78	873.90	89.72	12.22	9.32	5.71	12.52
05997F	bi-fuel	22306	493	399.93	1905	1143.78	938.17	79.44	11.78	9.30	6.00	12.70

Appendix B: Methods for Determining Combined Fuel Economy and Fuel Operating Cost

Data suitable for determining fuel economy, percent use of LPG, and fuel operating costs are available from both the vehicle operation log forms and the TxDOT database. However, data entries in the database are delayed and are neither date stamped nor mileage stamped (other than the final odometer reading) and, therefore, cannot be precisely aligned with the vehicle operation log forms. Thus, these two sources of data cannot yield precise agreement. However, over a reasonably long time period, such as the present project, discrepancies between the two will be minimized. The methods used to calculate the parameters that are related to the fuel operating cost are discussed in this appendix. Example calculations are provided in the final section.

Energy Contents of LPG and Gasoline

Because 31 of the 35 study vehicles were bi-fueled, determination of the combined fuel economy relied on the theoretical relationship between the chemical energy per LPG gallon and that for gasoline, as verified by results from this study (Table 2) and by prior investigations (Matthews et al., 1996; Chiu and Matthews, 1996; Wu et al., 1996, 1998a). The energy content (Net Heating Value) of a gallon of standard gasoline is defined in the U.S. Code of Federal Regulations (CFR 40, Section 600.113) to be 114,132 Btu/gallon. A standard energy content is not available for LPG because its composition varies depending on the source of the LPG (i.e., produced from crude oil or stripped from natural gas). However, a study of the LPG in Texas found that the Coefficient of Variability (the standard deviation normalized by the mean) of the mass-based Net Heating Value was less than 0.4%, and the mean was 19,967 Btu/lb (Wu et al., 1998b). The density of LPG is 4.2 lb/gallon. Thus, the volume-based Net Heating Value for the LPG in Texas is 83,861 Btu per LPG gallon. Taking the ratio of these two volume-based Net Heating Values yields the conclusion that 1.36 gallons of LPG has the same energy as 1 gallon of gasoline.

Equations

The following parameters are defined for the fuel economy, fuel operating cost, and percent LPG usage calculations:

- Vehicle operation log form, VOLF
- TxDOT database download, DB
- Total miles driven, TMD = [(odometer reading at end) – (odometer reading at start)] - [(odometer reading at new data entry) – (odometer reading before missing data entry)] over the project period, from VOLF
- Total LPG used, TPU = cumulative LPG used over the project period, from VOLF
- Total gasoline used, TGU = cumulative gasoline used over the project period, from VOLF
- Total cost of LPG used, TPC = cumulative LPG cost in the project period

Equations B.1-B.5 were used to perform calculations for the data on the vehicle operation log forms.

$$\text{TPC} [\text{\$}] = \text{TPU} [\text{LPG gallons}] * \text{SPC}' [\text{\$/LPG gallon}] \quad (\text{B.1})$$

where SPC' is the LPG cost calculated from TxDOT monthly records for the actual LPG purchase price (\\$/LPG gallon).

Total cost of gasoline used, TGC = cumulative gasoline cost in the project period:

$$\text{TGC} [\text{\$}] = \text{TGU} [\text{gasoline gallons}] * \text{SGC}' [\text{\$/gasoline gallon}] \quad (\text{B.2})$$

where SGC' is the gasoline cost paid by TxDOT.

Fuel operating cost, FOC, over the project period:

$$\text{FOC} [\text{\$/mile}] = (\text{TPC} + \text{TGC}) / \text{TMD} \quad (\text{B.3})$$

Combined fuel economy, CFE, over the project period:

$$\text{CFE} [\text{mpegg}] = \text{TMD} [\text{mi}] / (\{\text{TPU} [\text{LPG gallons}] * (1/1.36) [\text{gasoline gal./LPG gal.}]\} + \text{TGU} [\text{gasoline gallons}]) \quad (\text{B.4})$$

Percentage LPG used in this 6 month period, %LPG

$$\% \text{LPG} = \text{TPU} / (\text{TPU} + \text{TGU}) \quad (\text{B.5})$$

Similar calculations were done using the results from the TxDOT database via the following definitions and equations:

- Total miles driven, TMD' = over the project period, from DB
- Total LPG used, TPU' = cumulative LPG used over the project period, from DB
- Total gasoline used, TGU' = cumulative gasoline used over the project period, from DB
- Total cost of LPG used, TPC' = cumulative LPG cost over the project period, from DB

$$\text{TPC}' = \text{TPU}' * \text{SPC}' \quad (\text{B.6})$$

Total cost of gasoline used, TGC' = cumulative gasoline cost over the project period, from DB

Combined fuel economy, CFE', over the project period:

$$\text{CFE}' [\text{mpegg}] = \text{TMD}' [\text{mi}] / (\{\text{TPU}' [\text{LPG gallons}] * (1/1.36) [\text{gasoline gal./LPG gal.}]\} + \text{TGU}' [\text{gasoline gallons}]) \quad (\text{B.7})$$

Fuel operating cost, FOC', over the project period:

$$\text{FOC}' [\text{\$/mile}] = (\text{TPC}' + \text{TGC}') / \text{TMD}' \quad (\text{B.8})$$

Note that the TxDOT database's timelines are not as current as those of the vehicle operation log forms. TxDOT sent us data about our project vehicles each month, such as the cumulative fuel used since the vehicle went into service. The fuel usage for each month can be obtained by subtracting the corresponding data submitted during the previous month from those for the present month. Unfortunately, the data submitted by the local drivers to their districts and the timing of the districts entering of the data into the database are not fixed or regular. Therefore, the database records do not always correspond to the log form records for each specific vehicle. For example, the LPG usage of Vehicle 03556G in October 1997 was 92 gallons in TxDOT's

monthly data, but the vehicle operation log form showed the LPG usage in that month was 262.1 gallons.

To account for this, in the calculations presented above, the results are calculated over a long time (and/or mileage) increment. The advantage of this approach, when applied to the data from the vehicle operation log forms, is that it minimizes inaccuracies resulting from mismatches in the odometer reading and/or fuel quantity data for a specific refill. For the results from the TxDOT database, the advantages of this long-term approach are that it both compensates for data entry errors and for delays in data entry. However, for the analyses from the vehicle operation log forms, this approach suffers if a driver entirely skipped entering a record for a refill (in the case of the database, the fuel quantity will eventually get entered from the payment records via the Accounting Office). Thus, a third method for determining the combined fuel economy is analysis of the data on the vehicle operating log forms, combining the results for every refueling entry each month:

Combined incremental fuel economy, CIFE, over each monthly period:

$$\text{CIFE [mpegg]} = \text{IMD [mi]} / (\{\text{IPU [LPG gallons]} * (1/1.36) [\text{gasoline gal./LPG gal.}] \} + \text{IGU [gasoline gallons]}) \quad (\text{B.9})$$

where:

- Incremental miles driven, IMD = miles driven that month
- Incremental LPG usage, IPU = LPG gallons added that month
- Incremental gasoline usage, IGU = gasoline gallons added that month.

Statistical analysis of the results obtained via Equation B.9 should reveal outliers (unrealistically high values for the combined incremental fuel economy) that result from missing or incorrect refueling records on the vehicle operation log forms. Equation B.9 was also applied to the monthly database records, yielding the fourth measure of fuel economy. Outliers were identified as having a fuel economy that is more than two standard deviations from the mean. After elimination of these outliers, a revised average was calculated.

Example Calculations

As an example of the calculations performed, assume the following data for three vehicles:

Table B-1. Data for Example Calculations

ID	miles (TMD)	LPG gallons (TPU)	gasoline gallons (TGU)
1	10,160	0	800
2	9,338	1000	0
3	10,080	780	220

For the purpose of these example calculations, it will also be assumed that gasoline costs 80 cents/gallon and LPG costs 45 cents per actual LPG gallon. For each vehicle, the total propane cost (TPC) is:

$$\text{TPC}_{\#1} = \text{TPU} * \text{SPC} = 0 * \$.45 = \$0.00$$

$$\text{TPC}_{\#2} = \text{TPU} * \text{SPC} = 1000 * \$0.45 = \$450.00$$

$$\text{TPC}_{\#3} = \text{TPU} * \text{SPC} = 780 * \$0.45 = \$351.00$$

The total gasoline cost (TGC) is:

$$\text{TGC}_{\#1} = \text{TGU} * \text{SGC} = 800 * \$0.80 = \$640.00$$

$$\text{TGC}_{\#2} = \text{TGU} * \text{SGC} = 0 * \$0.80 = \$0.00$$

$$\text{TGC}_{\#3} = \text{TGU} * \text{SGC} = 220 * \$0.80 = \$176.00$$

The fuel operating cost is:

$$\text{FOC}_{\#1} = (\text{TPC} + \text{TGC}) / \text{TMD} = (\$0 + \$640) / 10,160 = 6.30¢ / \text{mile}$$

$$\text{FOC}_{\#2} = (\text{TPC} + \text{TGC}) / \text{TMD} = (\$450 + \$0) / 9,338 = 4.82¢ / \text{mile}$$

$$\text{FOC}_{\#3} = (\text{TPC} + \text{TGC}) / \text{TMD} = (\$351 + \$176) / 10,080 = 5.23¢ / \text{mile}$$

The percent LPG use (%LPG) is:

$$\% \text{LPG}_{\#1} = \text{TPU} / (\text{TPU} + \text{TGU}) = 100 * [0 / (0 + 800)] = 0.00\%$$

$$\% \text{LPG}_{\#2} = \text{TPU} / (\text{TPU} + \text{TGU}) = 100 * [1000 / (1000 + 0)] = 100.00\%$$

$$\% \text{LPG}_{\#3} = \text{TPU} / (\text{TPU} + \text{TGU}) = 100 * [780 / (780 + 220)] = 78.00\%$$

The combined fuel economy (CFE) is:

$$\text{CFE}_{\#1} = \frac{\text{TMD}}{(\text{TPU} / 1.36) + \text{TGU}} = \frac{10,160}{(0 / 1.36) + 800} = 12.7 \text{mpegg} = 12.7 \text{mi} / \text{gal}_{\text{gasoline}}$$

$$\text{CFE}_{\#2} = \frac{\text{TMD}}{(\text{TPU} / 1.36) + \text{TGU}} = \frac{9,338}{(1000 / 1.36) + 0} = 12.7 \text{mpegg}$$

$$\text{CFE}_{\#3} = \frac{\text{TMD}}{(\text{TPU} / 1.36) + \text{TGU}} = \frac{10,080}{(780 / 1.36) + 220} = 12.7 \text{mpegg}$$

Appendix C: Discussion of Statistics Related to Fuel Use

The statistics for the factors that are related to fuel use are discussed in this appendix. The fuel economy is discussed first, and includes a discussion of the meanings and uses of the statistical parameters.

Fuel Economy

Table C-1a presents the fuel economy statistics for the bi-fuel vehicles as determined using the four techniques discussed in Appendix B. Table C-1b presents the fuel economy statistics for the gasoline-only vehicles. Each of these tables will be discussed individually before the results for the bi-fuel vehicles are compared to those for the gasoline-only vehicles.

Table C-1a. Fuel Economy for the Bi-Fuel Vehicles in the Test Fleet

		bi-fuel vehicles			
		from logs		from database	
		CFE	CIFE	CFE'	CIFE'
		Combined Fuel Economy	Avg. CIFE excl. outliers	Combined Fuel Economy	Avg. CIFE excl. outliers
		[mpegg]	[mpegg]	[mpegg]	[mpegg]
No. of Data Points		31	31	31	31
Calculated Mean		12.50	12.75	12.35	12.68
95% Conf. Interval for the True Mean	Lower Bound	11.82	12.17	11.84	12.06
	Upper Bound	13.18	13.34	12.85	13.29
Coeff. of Variability (%)		14.8	12.5	11.3	13.2

In Table C-1a, the calculated mean for the combined fuel economy of the bi-fuel vehicles, in miles per equivalent gallon of gasoline, is almost the same for the two separate calculations applied to each of the two databases. However, there is no fundamental physical reason to expect any difference in these four results. One of the factors that complicates the determination of the average fuel economy is that each vehicle had a different duty cycle. The duty cycle, or driving schedule, has a strong effect on the fuel economy (e.g., the difference between the urban and highway fuel economy of any given vehicle). In Table C-1a, this effect is quantified via the Coefficient of Variability of the fuel economy. The CoV is the standard deviation normalized by the mean, and is between ~11% and ~15% for these bi-fuel vehicles. The major reason that the four calculations do not yield precisely identical averages is that the statistical basis for the calculations is relatively small. Statistics can be used to examine the distribution of fuel economies from the individual observations to determine—with 95% confidence—the range of fuel economies in which the true mean must occur. For example, the long-term data from the log forms indicates that the true mean for the fuel economy lies in the range of 11.82-13.18 mpegg with 95% confidence. Given the four different statistical analyses for the combined fuel economy of the bi-fuel vehicles, the overlaps in the 95% confidence intervals can be used to determine that the true mean must lie within the range of 12.17-12.85 mpegg. The fact that the four values for the calculated mean are all within this confidence interval means that *it cannot be*

stated with 95% confidence that these four means are statistically different. This, of course, is the expected result—the four different methods for calculating the combined fuel economy should not yield different answers. Because the database records are complete whereas the log form records have some missing data (see Appendix A), and because high or low outliers have been excluded in the calculation of the combined incremental fuel economy (as explained in Appendix B), it is estimated that the bi-fuel vehicles have a combined fuel economy of ~12.7 mpegg.

Table C-1b. Fuel Economy for the Gasoline-Only Vehicles in the Test Fleet

		gasoline-only vehicles			
		from logs		from database	
		CFE	CIFE	CFE'	CIFE'
		Combined Fuel Economy	Avg. CIFE excl. outliers	Combined Fuel Economy	Avg. CIFE excl. outliers
		[mpg]	[mpg]	[mpg]	[mpg]
No. of Data Points		4	4	3	3
Calculated Mean		14.73	14.62	14.37	13.17
95% Conf. Interval for the True Mean	Lower Bound	13.00	13.09	11.05	10.75
	Upper Bound	16.46	16.15	17.68	15.59
Coeff. of Variability (%)		7.4	6.6	9.3	7.4

Table C-1b presents the statistics for the fuel economy of the gasoline-only vehicles. In this case, the size of the statistical sample is an order of magnitude smaller than for the bi-fuel vehicles. The four methods for calculating the fuel economy for the gasoline-only vehicles yield means that range from 13.17 mpg to 14.73 mpg (11.8% higher). However, the 95% confidence intervals for where the true mean lies encompass all four of these means. In other words, it cannot be said with at least 95% confidence that these four measures yield statistically different results. Additionally, the results obtained by analyzing the log form data for the gasoline-only vehicles are less reliable than those from the database records are for two reasons. Most importantly, several months of log form data are missing for one of the gasoline-only vehicles. Also, the log form data includes the gasoline-only vehicle retained by UT whereas the database records do not. This vehicle was not in daily service for TxDOT and thus had a different duty cycle. In fact, it had the fourth highest fuel economy among all 35 of the test vehicles. Therefore, the database records are both more complete and more representative of the gasoline-only vehicles in TxDOT service. Combining the 95% confidence intervals for the database statistics indicates that the true mean for the fuel economy of the gasoline-only vehicles lies between 11.05 mpg and 15.59 mpg. This encompasses all four means calculated for the bi-fuel vehicles. Thus, it cannot be stated with 95% confidence that the fuel economy of the gasoline-only vehicles is statistically different from the gasoline-energy-equivalent fuel economy of the bi-fuel vehicles (~12.7 mpegg). This result is also expected based upon prior research (Matthews et al., 1996; Chiu and Matthews, 1996; Wu et al., 1996, 1998a) as verified by results from the present study (Table 2).

Percent LPG Used

Table C-2 presents the statistics regarding the percent use of LPG. Data from both the vehicle operation log forms and the TxDOT database were used to generate the results that are summarized in Table C-2. The means from these two data sets are not statistically different because of the broad 95% confidence intervals for the value of the true mean. From these results it is estimated that the bi-fuel vehicles in the test fleet average ~78% use of LPG.

Table C-2. Summary Statistics for the Percent LPG Used

		from logs	from database
		%LPG	%LPG'
		actual gallons	actual gallons
No. of Data Points		31	31
Calculated Mean		80.13	76.84
95% Conf. Interval for the True Mean	Lower Bound	75.08	71.48
	Upper Bound	85.18	82.19
Coeff. of Variability (%)		17.2	19.0

Gasoline and LPG Purchase Prices

The average prices for LPG and gasoline shown in Table C-3 were obtained from monthly average purchase prices provided by TxDOT for a 16-month period during this project. For LPG, average monthly prices were obtained from both the Houston and Corpus Christi districts since each has an independent contract for LPG. The ~\$0.80 per gallon average for gasoline reflects both the discount for bulk purchase and the fact that state agencies do not pay the federal tax on gasoline. Here, it should again be noted that the gasoline price includes state tax paid at the pump whereas the LPG price does not. Instead, the state "road tax" for LPG is paid via an annual tax on the alternative fuels, as discussed in the body of this report. The mean gasoline price was 79.79 cents/gallon and that for LPG (averaging over both Houston and Corpus) was 55.64 cents per actual LPG gallon. These two means are statistically different because the 95% confidence intervals do not overlap. The mean price of LPG in the Houston district was 49.52 cents per actual LPG gallon (67.35 cents per equivalent gasoline gallon) and that for the Corpus district was 61.75 cents per actual LPG gallon (83.98 cents per equivalent gasoline gallon).

Table C-3. Average LPG and Gasoline Prices for the 34 TxDOT Vehicles

		Gasoline price	Corpus LPG price	Houston LPG price	avg. LPG price
		(cents/gal)	(cents/gal)	(cents/gal)	(cents/gal)
No. of Data Points		16	16	16	32
Calculated Mean		79.79	61.75	49.52	55.64
95% Conf. Interval for the True Mean	Lower Bound	76.01	58.90	46.67	52.70
	Upper Bound	83.58	64.60	52.37	58.57
Coeff. of Variability (%)		8.90	8.66	10.80	14.64

Fuel Operating Costs

Table C-4 provides the results for the fuel operating cost. Only the results from the database records are shown because these records were complete whereas some of the log form data was missing. The gasoline-only vehicle retained by UT has a log form but is not in the TxDOT database. Because this vehicle was not in daily service for TxDOT, the fuel operating cost from the database records is the better indicator for the TxDOT fleet. Comparison of the raw means indicates that the fuel operating cost for the gasoline-only vehicles is lower than that for the bi-fuel vehicles, including those in Houston that purchase LPG at 12.44 cents per equivalent gallon cheaper than gasoline. This result is caused by the very small statistical basis for the gasoline-only vehicles. The small basis for the gasoline-only vehicles is reflected by the broad 95% confidence interval for the value of the true mean: 4-7 cents/mile. Because the 95% confidence interval for the fuel operating cost of the gasoline-only vehicles overlaps the means for the bi-fuel vehicles, it cannot be said with 95% confidence that the fuel operating cost is different for the gasoline-only and bi-fuel vehicles. Because the number of the gasoline-only vehicles is an order of magnitude smaller than for the bi-fuel vehicles, differences in the duty cycle from one vehicle to the next have a much stronger influence on the fuel economy for the gasoline-only vehicles than for the bi-fuel vehicles. This is precisely why this uncontrolled variable (fuel economy) has been factored out in the discussions in the body of the report.

Table C-4. Summary Statistics for the Fuel Operating Cost
(from the database records)

		all bi-fuel vehicles	Corpus bi-fuel vehicles	Houston bi-fuel vehicles	gasoline only vehicles
		fuel operating cost	fuel operating cost	fuel operating cost	fuel operating cost
		(cents/mile)	(cents/mile)	(cents/mile)	(cents/mile)
No. of Data Points		31	16	15	3
Calculated Mean		6.27	6.52	6.00	5.55
95% Conf. Interval for True Mean	Lower Bound	6.00	6.13	5.66	4.04
	Upper Bound	6.53	6.91	6.33	7.07
Coeff. of Variability (%)		11.4	11.3	10.0	11.0

**Appendix D:
Detailed Maintenance and Repair Data
and Cost Summaries**

Table D.1. Scheduled Maintenance Cost Summary by Vehicle

scheduled maintenance							
TxDOT Eqpt. No.	type	miles driven in 16 months (database)	Scheduled maintenance parts cost [\$]	Scheduled maintenance labor cost [\$]	Scheduled maintenance other cost [\$]	Total Scheduled maintenance cost [\$]	Total scheduled maintenance operating cost [cents/mi]
03556G	bi-fuel	24066.0	52.50	150.00	12.00	214.50	0.89
03558G	bi-fuel	30523.0	78.75	215.50	18.00	312.25	1.02
03562G	bi-fuel	38438.0	105.00	300.00	24.00	429.00	1.12
03563G	bi-fuel	12405.0	8.75	50.00	2.00	60.75	0.49
03570G	bi-fuel	33208.0	61.25	175.00	14.00	250.25	0.75
03574G	bi-fuel	24798.0	37.00	100.00	6.50	143.50	0.58
03575G	bi-fuel	14221.0	43.75	125.00	10.00	178.75	1.26
03577G	bi-fuel	18512.0	35.00	100.00	8.00	143.00	0.77
03578G	bi-fuel	15551.0	17.50	50.00	4.00	71.50	0.46
03579G	bi-fuel	28440.0	52.50	150.00	12.00	214.50	0.75
03625G	bi-fuel	35726.0	78.75	225.00	18.00	321.75	0.90
03626G	bi-fuel	52514.0	105.00	327.75	24.00	456.75	0.87
05414F	bi-fuel	16012.0	36.25	86.95	6.00	129.20	0.81
05415F	bi-fuel	25953.0	61.25	175.00	14.00	250.25	0.96
05418F	bi-fuel	9294.0	17.50	50.00	4.00	71.50	0.77
05419F	bi-fuel	32774.0	61.25	175.00	14.00	250.25	0.76
03644G	bi-fuel	12714.0	22.00	16.00	4.00	42.00	0.33
03649G	bi-fuel	13284.0	41.75	49.00	8.00	98.75	0.74
03651G	bi-fuel	13563.0	44.00	32.00	8.00	84.00	0.62
03652G	bi-fuel	11991.0	44.00	32.00	8.00	84.00	0.70
03655G	bi-fuel	5361.0	22.00	16.00	4.00	42.00	0.78
05971F	bi-fuel	11325.0	33.00	24.00	6.00	63.00	0.56
05972F	bi-fuel	6934.0	22.00	16.00	4.00	42.00	0.61
05974F	bi-fuel	19979.0	77.90	79.00	12.00	168.90	0.85
05975F	bi-fuel	23430.0	77.00	56.00	14.00	147.00	0.63
05976F	bi-fuel	16807.0	52.00	24.00	8.00	84.00	0.50
05992F	bi-fuel	21494.0	77.00	56.00	14.00	147.00	0.68
05994F	bi-fuel	21269.0	66.00	48.00	12.00	126.00	0.59
05995F	bi-fuel	20088.0	77.00	56.00	14.00	147.00	0.73
05996F	bi-fuel	17379.0	37.58	40.00	4.00	81.58	0.47
05997F	bi-fuel	20552.0	77.00	56.00	14.00	147.00	0.72
UT	gasoline	32317.4	116.07	86.99	8.00	211.06	0.65
04353G	gasoline	19379.0	66.00	48.00	12.00	126.00	0.65
04354G	gasoline	14692.0	66.00	48.00	12.00	126.00	0.86
04355G	gasoline	38806.0	57.00	116.00	12.00	185.00	0.48

Table D.2. Repair Cost (Unscheduled maintenance) Summary by Vehicle

overall repair costs (\$)						
TxDOT Eqpt. No.	type	miles driven in 16 months (database)	Unscheduled maintenance parts cost [\$]	Unscheduled maintenance labor cost [\$]	Unscheduled maintenance other cost [\$]	Total unscheduled maintenance cost [\$]
03556G	bi-fuel	24066.0	1052.03	992.64		2044.67
03558G	bi-fuel	30523.0	239.96	1347.14		1587.10
03562G	bi-fuel	38438.0	310.64	97.34		407.98
03563G	bi-fuel	12405.0	23.30	168.86		192.16
03570G	bi-fuel	33208.0	145.07	673.04		818.11
03574G	bi-fuel	24798.0	131.05	589.01		720.06
03575G	bi-fuel	14221.0	167.68	58.80		226.48
03577G	bi-fuel	18512.0	464.79	580.04		1044.83
03578G	bi-fuel	15551.0	70.00	267.52		337.52
03579G	bi-fuel	28440.0	303.59	309.50		613.09
03625G	bi-fuel	35726.0	73.22	0.00		73.22
03626G	bi-fuel	52514.0	376.42	838.46	27.22	1242.10
05414F	bi-fuel	16012.0	120.94	117.84		238.78
05415F	bi-fuel	25953.0	104.61	274.54		379.15
05418F	bi-fuel	9294.0				0.00
05419F	bi-fuel	32774.0	1488.65	1383.40		2872.05
03644G	bi-fuel	12714.0	78.50	119.64		198.14
03649G	bi-fuel	13284.0		145.68		145.68
03651G	bi-fuel	13563.0		36.42		36.42
03652G	bi-fuel	11991.0		36.42		36.42
03655G	bi-fuel	5361.0		145.68		145.68
05971F	bi-fuel	11325.0	72.00	364.00	5.94	441.94
05972F	bi-fuel	6934.0				0.00
05974F	bi-fuel	19979.0	1689.54	985.54		2675.08
05975F	bi-fuel	23430.0	17.26	196.68		213.94
05976F	bi-fuel	16807.0		218.52		218.52
05992F	bi-fuel	21494.0				0.00
05994F	bi-fuel	21269.0		36.42		36.42
05995F	bi-fuel	20088.0		97.84		97.84
05996F	bi-fuel	17379.0	864.45	942.39	40.00	1846.84
05997F	bi-fuel	20552.0	65.56	107.90		173.46
UT	gasoline	32317.4		10.00		10.00
04353G	gasoline	19379.0	34.52	26.00		60.52
04354G	gasoline	14692.0	216.15	132.84		348.99
04355G	gasoline	38806.0				0.00

Table D.3. Repair Cost Summary in Cents per Mile (by vehicle)

overall repair operating costs (cents/mile)						
TxDOT Eqpt. No.	type	miles driven in 16 months (database)	Unscheduled maintenance operating parts costs [cents/mi]	Unscheduled maintenance operating labor costs [cents/mi]	Unscheduled maintenance operating other costs [cents/mi]	Total unscheduled maintenance operating costs (cents/mile)
03556G	bi-fuel	24066.0	4.37	4.12	0.00	8.50
03558G	bi-fuel	30523.0	0.79	4.41	0.00	5.20
03562G	bi-fuel	38438.0	0.81	0.25	0.00	1.06
03563G	bi-fuel	12405.0	0.19	1.36	0.00	1.55
03570G	bi-fuel	33208.0	0.44	2.03	0.00	2.46
03574G	bi-fuel	24798.0	0.53	2.38	0.00	2.90
03575G	bi-fuel	14221.0	1.18	0.41	0.00	1.59
03577G	bi-fuel	18512.0	2.51	3.13	0.00	5.64
03578G	bi-fuel	15551.0	0.45	1.72	0.00	2.17
03579G	bi-fuel	28440.0	1.07	1.09	0.00	2.16
03625G	bi-fuel	35726.0	0.20	0.00	0.00	0.20
03626G	bi-fuel	52514.0	0.72	1.60	0.05	2.37
05414F	bi-fuel	16012.0	0.76	0.74	0.00	1.49
05415F	bi-fuel	25953.0	0.40	1.06	0.00	1.46
05418F	bi-fuel	9294.0	0.00	0.00	0.00	0.00
05419F	bi-fuel	32774.0	4.54	4.22	0.00	8.76
03644G	bi-fuel	12714.0	0.62	0.94	0.00	1.56
03649G	bi-fuel	13284.0	0.00	1.10	0.00	1.10
03651G	bi-fuel	13563.0	0.00	0.27	0.00	0.27
03652G	bi-fuel	11991.0	0.00	0.30	0.00	0.30
03655G	bi-fuel	5361.0	0.00	2.72	0.00	2.72
05971F	bi-fuel	11325.0	0.64	3.21	0.05	3.90
05972F	bi-fuel	6934.0	0.00	0.00	0.00	0.00
05974F	bi-fuel	19979.0	8.46	4.93	0.00	13.39
05975F	bi-fuel	23430.0	0.07	0.84	0.00	0.91
05976F	bi-fuel	16807.0	0.00	1.30	0.00	1.30
05992F	bi-fuel	21494.0	0.00	0.00	0.00	0.00
05994F	bi-fuel	21269.0	0.00	0.17	0.00	0.17
05995F	bi-fuel	20088.0	0.00	0.49	0.00	0.49
05996F	bi-fuel	17379.0	4.97	5.42	0.23	10.63
05997F	bi-fuel	20552.0	0.32	0.53	0.00	0.84
UT	gasoline	32317.4	0.00	0.03	0.00	0.03
04353G	gasoline	19379.0	0.18	0.13	0.00	0.31
04354G	gasoline	14692.0	1.47	0.90	0.00	2.38
04355G	gasoline	38806.0	0.00	0.00	0.00	0.00

Table D.4. LPG-related Repair Cost Summary (by vehicle)

LPG-related repair costs (\$)						
TxDOT Eqpt. No.	type	miles driven in 16 months (database)	LPG related repair parts costs [\$]	LPG related repair labor costs [\$]	LPG related repair other costs [\$]	LPG related repair total costs [\$]
03556G	bi-fuel	24066.0	940.49	666.68		1607.17
03558G	bi-fuel	30523.0	144.38	39.20		183.58
03562G	bi-fuel	38438.0	293.38	72.84		366.22
03563G	bi-fuel	12405.0	23.30	56.02		79.32
03570G	bi-fuel	33208.0	145.07	673.04		818.11
03574G	bi-fuel	24798.0				
03575G	bi-fuel	14221.0	167.68	58.80		226.48
03577G	bi-fuel	18512.0				
03578G	bi-fuel	15551.0		218.52		218.52
03579G	bi-fuel	28440.0	286.33	207.26		493.59
03625G	bi-fuel	35726.0				
03626G	bi-fuel	52514.0	213.82	490.02	27.22	731.06
05414F	bi-fuel	16012.0				
05415F	bi-fuel	25953.0				
05418F	bi-fuel	9294.0				
05419F	bi-fuel	32774.0	144.38	184.88		329.26
03644G	bi-fuel	12714.0				
03649G	bi-fuel	13284.0				
03651G	bi-fuel	13563.0				
03652G	bi-fuel	11991.0				
03655G	bi-fuel	5361.0				
05971F	bi-fuel	11325.0				
05972F	bi-fuel	6934.0				
05974F	bi-fuel	19979.0	475.09	385.54		860.63
05975F	bi-fuel	23430.0				
05976F	bi-fuel	16807.0		145.68		145.68
05992F	bi-fuel	21494.0				
05994F	bi-fuel	21269.0				
05995F	bi-fuel	20088.0				
05996F	bi-fuel	17379.0				
05997F	bi-fuel	20552.0	23.30			23.30

Table D.5. LPG-related Repair Cost Summary in Cents per Mile (by vehicle)

LPG-related repair operating costs (cents/mile)						
TxDOT Eqpt. No.	type	miles driven in 16 months (database)	LPG related repair operating parts costs [cents/mi]	LPG related repair operating labor costs [cents/mi]	LPG related repair operating other costs [cents/mi]	LPG related repair operating total costs [cents/mi]
03556G	bi-fuel	24066.0	3.91	2.77	0.00	6.68
03558G	bi-fuel	30523.0	0.47	0.13	0.00	0.60
03562G	bi-fuel	38438.0	0.76	0.19	0.00	0.95
03563G	bi-fuel	12405.0	0.19	0.45	0.00	0.64
03570G	bi-fuel	33208.0	0.44	2.03	0.00	2.46
03574G	bi-fuel	24798.0				
03575G	bi-fuel	14221.0	1.18	0.41	0.00	1.59
03577G	bi-fuel	18512.0				
03578G	bi-fuel	15551.0	0.00	1.41	0.00	1.41
03579G	bi-fuel	28440.0	1.01	0.73	0.00	1.74
03625G	bi-fuel	35726.0				
03626G	bi-fuel	52514.0	0.41	0.93	0.05	1.39
05414F	bi-fuel	16012.0				
05415F	bi-fuel	25953.0				
05418F	bi-fuel	9294.0				
05419F	bi-fuel	32774.0	0.44	0.56	0.00	1.00
03644G	bi-fuel	12714.0				
03649G	bi-fuel	13284.0				
03651G	bi-fuel	13563.0				
03652G	bi-fuel	11991.0				
03655G	bi-fuel	5361.0				
05971F	bi-fuel	11325.0				
05972F	bi-fuel	6934.0				
05974F	bi-fuel	19979.0	2.38	1.93	0.00	4.31
05975F	bi-fuel	23430.0				
05976F	bi-fuel	16807.0	0.00	0.87	0.00	0.87
05992F	bi-fuel	21494.0				
05994F	bi-fuel	21269.0				
05995F	bi-fuel	20088.0				
05996F	bi-fuel	17379.0				
05997F	bi-fuel	20552.0	0.11	0.00	0.00	0.11

Table D.6. Non-LPG-related Repair Cost Summary (by vehicle)

non-LPG-related repair costs (\$)						
TxDOT Eqpt. No.	type	miles driven in 16 months (database)	Non-LPG related repair parts costs [\$]	Non-LPG related repair labor costs [\$]	Non-LPG related repair other costs [\$]	Non-LPG related repair total costs [\$]
03556G	bi-fuel	24066.0	111.54	325.96		437.50
03558G	bi-fuel	30523.0	95.58	1307.94		1403.52
03562G	bi-fuel	38438.0	17.26	24.50		41.76
03563G	bi-fuel	12405.0	0.00	112.84		112.84
03570G	bi-fuel	33208.0	0.00	0.00		0.00
03574G	bi-fuel	24798.0	131.05	589.01		720.06
03575G	bi-fuel	14221.0	0.00	0.00		0.00
03577G	bi-fuel	18512.0	464.79	580.04		1044.83
03578G	bi-fuel	15551.0	70.00	49.00		119.00
03579G	bi-fuel	28440.0	17.26	102.24		119.50
03625G	bi-fuel	35726.0	73.22	0.00		73.22
03626G	bi-fuel	52514.0	162.60	348.44		511.04
05414F	bi-fuel	16012.0	120.94	117.84		238.78
05415F	bi-fuel	25953.0	104.61	274.54		379.15
05418F	bi-fuel	9294.0	0.00	0.00		0.00
05419F	bi-fuel	32774.0	1344.27	1198.52		2542.79
03644G	bi-fuel	12714.0	78.50	119.64		198.14
03649G	bi-fuel	13284.0	0.00	145.68		145.68
03651G	bi-fuel	13563.0	0.00	36.42		36.42
03652G	bi-fuel	11991.0	0.00	36.42		36.42
03655G	bi-fuel	5361.0	0.00	145.68		145.68
05971F	bi-fuel	11325.0	72.00	364.00	5.94	441.94
05972F	bi-fuel	6934.0	0.00	0.00		0.00
05974F	bi-fuel	19979.0	1214.45	600.00		1814.45
05975F	bi-fuel	23430.0	17.26	196.68		213.94
05976F	bi-fuel	16807.0	0.00	72.84		72.84
05992F	bi-fuel	21494.0	0.00	0.00		0.00
05994F	bi-fuel	21269.0	0.00	36.42		36.42
05995F	bi-fuel	20088.0	0.00	97.84		97.84
05996F	bi-fuel	17379.0	864.45	942.39	40.00	1846.84
05997F	bi-fuel	20552.0	42.26	107.90		150.16
UT	gasoline	32317.4	0.00	10.00		10.00
04353G	gasoline	19379.0	34.52	26.00		60.52
04354G	gasoline	14692.0	216.15	132.84		348.99
04355G	gasoline	38806.0	0.00	0.00		0.00

Table D.7. Non-LPG-related Repair Cost Summary in Cents per Mile (by vehicle)

non-LPG-related repair operating costs (cents/mile)						
TxDOT Eqpt. No.	type	miles driven in 16 months (database)	Non-LPG related repair operating parts costs [cents/mi]	Non-LPG related repair operating labor costs [cents/mi]	Non-LPG related repair operating other costs [cents/mi]	Non-LPG related repair operating total costs [cents/mi]
03556G	bi-fuel	24066.0	0.46	1.35	0.00	1.82
03558G	bi-fuel	30523.0	0.31	4.29	0.00	4.60
03562G	bi-fuel	38438.0	0.04	0.06	0.00	0.11
03563G	bi-fuel	12405.0	0.00	0.91	0.00	0.91
03570G	bi-fuel	33208.0	0.00	0.00	0.00	0.00
03574G	bi-fuel	24798.0	0.53	2.38	0.00	2.90
03575G	bi-fuel	14221.0	0.00	0.00	0.00	0.00
03577G	bi-fuel	18512.0	2.51	3.13	0.00	5.64
03578G	bi-fuel	15551.0	0.45	0.32	0.00	0.77
03579G	bi-fuel	28440.0	0.06	0.36	0.00	0.42
03625G	bi-fuel	35726.0	0.20	0.00	0.00	0.20
03626G	bi-fuel	52514.0	0.31	0.66	0.00	0.97
05414F	bi-fuel	16012.0	0.76	0.74	0.00	1.49
05415F	bi-fuel	25953.0	0.40	1.06	0.00	1.46
05418F	bi-fuel	9294.0	0.00	0.00	0.00	0.00
05419F	bi-fuel	32774.0	4.10	3.66	0.00	7.76
03644G	bi-fuel	12714.0	0.62	0.94	0.00	1.56
03649G	bi-fuel	13284.0	0.00	1.10	0.00	1.10
03651G	bi-fuel	13563.0	0.00	0.27	0.00	0.27
03652G	bi-fuel	11991.0	0.00	0.30	0.00	0.30
03655G	bi-fuel	5361.0	0.00	2.72	0.00	2.72
05971F	bi-fuel	11325.0	0.64	3.21	0.05	3.90
05972F	bi-fuel	6934.0	0.00	0.00	0.00	0.00
05974F	bi-fuel	19979.0	6.08	3.00	0.00	9.08
05975F	bi-fuel	23430.0	0.07	0.84	0.00	0.91
05976F	bi-fuel	16807.0	0.00	0.43	0.00	0.43
05992F	bi-fuel	21494.0	0.00	0.00	0.00	0.00
05994F	bi-fuel	21269.0	0.00	0.17	0.00	0.17
05995F	bi-fuel	20088.0	0.00	0.49	0.00	0.49
05996F	bi-fuel	17379.0	4.97	5.42	0.23	10.63
05997F	bi-fuel	20552.0	0.21	0.53	0.00	0.73
UT	gasoline	32317.4	0.00	0.03	0.00	0.03
04353G	gasoline	19379.0	0.18	0.13	0.00	0.31
04354G	gasoline	14692.0	1.47	0.90	0.00	2.38
04355G	gasoline	38806.0	0.00	0.00	0.00	0.00

Table D.8. Summary of Reliability Rates (by vehicle)

reliability (repair rates)						
TxDOT Eqpt. No.	type	miles driven in 16 months (database)	Total repairs in this 16 months	Total LPG related repairs in this 16 months	Total repairs/5000 miles	Total LPG related repairs/5000 miles
03556G	bi-fuel	24066.0	7	4	1.45	0.83
03558G	bi-fuel	30523.0	7	1	1.15	0.16
03562G	bi-fuel	38438.0	2	1	0.26	0.13
03563G	bi-fuel	12405.0	2	1	0.81	0.40
03570G	bi-fuel	33208.0	1	1	0.15	0.15
03574G	bi-fuel	24798.0	5		1.01	
03575G	bi-fuel	14221.0	1	1	0.35	0.35
03577G	bi-fuel	18512.0	6		1.62	
03578G	bi-fuel	15551.0	2	1	0.64	0.32
03579G	bi-fuel	28440.0	2	1	0.35	0.18
03625G	bi-fuel	35726.0	2		0.28	
03626G	bi-fuel	52514.0	10	1	0.95	0.10
05414F	bi-fuel	16012.0	3		0.94	
05415F	bi-fuel	25953.0	5		0.96	
05418F	bi-fuel	9294.0				
05419F	bi-fuel	32774.0	5	1	0.76	0.15
03644G	bi-fuel	12714.0	2		0.79	
03649G	bi-fuel	13284.0	3		1.13	
03651G	bi-fuel	13563.0	1		0.37	
03652G	bi-fuel	11991.0	1		0.42	
03655G	bi-fuel	5361.0	2		1.87	
05971F	bi-fuel	11325.0	1		0.44	
05972F	bi-fuel	6934.0				
05974F	bi-fuel	19979.0	5	1	1.25	0.25
05975F	bi-fuel	23430.0	5		1.07	
05976F	bi-fuel	16807.0	2	1	0.59	0.30
05992F	bi-fuel	21494.0				
05994F	bi-fuel	21269.0	1		0.24	
05995F	bi-fuel	20088.0	2		0.50	
05996F	bi-fuel	17379.0	8		2.30	
05997F	bi-fuel	20552.0	4	1	0.97	0.24
UT	gasoline	32317.4	1		0.15	
04353G	gasoline	19379.0	4		1.03	
04354G	gasoline	14692.0	2		0.68	
04355G	gasoline	38806.0				

Appendix E: Statistics for Scheduled and Unscheduled Maintenance and Reliability

The statistical analyses for scheduled maintenance, repairs, and reliability are discussed in the following subsections. The statistical tables should be interpreted following the discussion in Appendix C.

Scheduled Maintenance

Table E-1 provides the summary statistics for scheduled maintenance, as divided into parts, labor, "other" (e.g., used oil disposal), and total. We constructed 95% confidence intervals for the difference between the means for the bi-fuel vehicles in Corpus and Houston for parts, labor, and other costs. Because permanent oil filters are used in the Corpus District, Table E-1 reflects a 38% lower parts cost but also a 132% higher labor cost for scheduled maintenance in the Corpus District than the Houston District. All of the statistical intervals comparing the means contain 0 except the labor interval; the difference in the cost of labor for scheduled maintenance is statistically different for the Corpus bi-fuel vehicles in comparison to those from the Houston District. This is due to the higher labor cost for cleaning the reusable oil filters in the Corpus Christi District.

Because all of the TxDOT vehicles perform scheduled maintenance on the suggested "harsh service" rate of, nominally, every 3 months or 3,000 miles, the scheduled maintenance costs are expected to be the same for both the bi-fuel and gasoline-only vehicles if both use the same type of oil filter. That is, because the Houston District and all 4 of the gasoline-only vehicles used replacement-type oil filters, it is expected that the costs for scheduled maintenance should be the same for the bi-fuel vehicles in the Houston District as for the gasoline-only vehicles. As expected, the mean parts costs, labor costs, other costs, and total costs are nearly identical for the bi-fuel vehicles in the Houston District as for the gasoline-only vehicles. All of the 95% confidence intervals for the differences between the means contain the value 0. Therefore, it cannot be stated with 95% confidence that these means are statistically different. Again, this is the expected result—the costs for routine scheduled maintenance should be independent of whether it is a bi-fuel vehicle or a gasoline-only vehicle. Comparison of the gasoline controls to the bi-fuel vehicles in the Houston District yields the estimate that the mean total cost for scheduled maintenance is ~0.65 cents/mile for both gasoline-only vehicles and bi-fuel vehicles that have replacement-type oil filters.

Table E.1. Summary Statistics for Scheduled Maintenance

		Bi-fuel vehicles								Gasoline control vehicles			
		Corpus Christi District				Houston District				Corpus Christi, Houston, and UT			
		Parts Costs	Labor Costs	Other Costs	Total Costs	Parts Costs	Labor Costs	Other Costs	Total Costs	Parts Costs	Labor Costs	Other Costs	Total Costs
		(cents/mi)	(cents/mi)	(cents/mi)	(cents/mi)	(cents/mi)	(cents/mi)	(cents/mi)	(cents/mi)	(cents/mi)	(cents/mi)	(cents/mi)	(cents/mi)
No. of Data Points		16	16	16	16	15	15	15	15	4	4	4	4
Calculated Mean		0.20	0.58	0.04	0.82	0.32	0.25	0.06	0.63	0.33	0.29	0.05	0.66
95% Conf. Interval for the True Mean	Lower Bound	0.17	0.50	0.04	0.71	0.29	0.21	0.03	0.56	0.12	0.23	0.00	0.41
	Upper Bound	0.23	0.65	0.05	0.94	0.36	0.29	0.08	0.71	0.53	0.34	0.09	0.91
Coeff. of Variability (%)		29.5	24.7	28.5	25.7	19.7	28.0	31.5	21.0	38.8	12.2	58.0	23.6

Unscheduled Maintenance

All but three of the study vehicles were under warranty throughout the project. Therefore, virtually all of the repairs were performed at no cost to TxDOT. However, TxDOT generally keeps their vehicles until well after 36,000 miles. Therefore, it was of interest to project the repair costs that might be expected after the expiration of the warranty. The method of projecting these costs was discussed in the main body of the report.

The means for the projected (post-warranty) repair costs are presented in Table E-2. Repairs do not occur on a regular schedule; many of the test vehicles had no repairs over the duration of the project whereas one had 8 repairs in less than 20,000 miles. Repairs do not follow a normal distribution (at least for this small pool of vehicles, all of which have relatively low mileage), as illustrated in Figures E-1 and E-2. Therefore, a statistical analysis based upon a normal distribution such as those presented previously is not possible. Furthermore, the very small sample size for the gasoline-only vehicles yields a large uncertainty in the validity of the mean repair cost for the gasoline-only vehicles. The sparsity of the gasoline-only data set can be addressed by examining the difference between the LPG-related maintenance and the total unscheduled maintenance for the bi-fuel vehicles; this is the portion of unscheduled maintenance that is expected to have occurred even if the vehicle had not been converted to bi-fuel operation. As shown in Figure E-1, ten of the 35 vehicles had non-LPG related repair costs in the range of 0 to 0.25 cents/mile whereas 9 of the 35, including one of the gasoline-only vehicles, had a repair cost of more than 2 cents/mile. The average non-LPG-related maintenance operating cost for the bi-fuel vehicles is 1.98 cents/mile. Because this is based upon a much larger sample size than is the mean for the 4 gasoline-only vehicles, and includes only repairs that were not related to the LPG system, it is estimated that the mean repair cost after the warranty period will be 1.98 cents/mile whether or not the vehicle has an LPG system.

It is expected that the repair costs for the bi-fuel vehicles will be higher simply because there is additional hardware on these vehicles. Figure E-2 shows that 19 of the 31 bi-fuel vehicles had an LPG-related repair cost between 0 and 0.25 cents/mile and only 3 of the 31 had an LPG-related repair cost of more than 2 cents/mile. As shown in Table E-2, on average the additional hardware for the LPG system adds 0.77 cents/mile to the unscheduled maintenance operating cost of the bi-fuel vehicles. That is, the bi-fuel vehicles are projected to have a repair cost that is 39% higher than that estimated for gasoline-only operation.

Although there is a large uncertainty in both the baseline repair cost (1.98 cents/mile) and the additional cost for LPG system repairs (0.77 cents/mile), these are the best values that can be extracted from the present data. Development of more accurate results requires observation over a longer period (more miles accumulated) and a larger pool of test vehicles, especially gasoline-only vehicles.

Table E-2. Summary Statistics for Unscheduled Maintenance

	bi-fuel vehicles			gasoline-only vehicles
	Total Repair Operating Costs	LPG Related Operating Costs	Non-LPG Related Operating Costs	Total Repair Operating Costs
	(cents/mile)	(cents/mile)	(cents/mile)	(cents/mile)
No. of Data Points	31	31	31	4
Mean	2.74	0.77	1.98	0.68

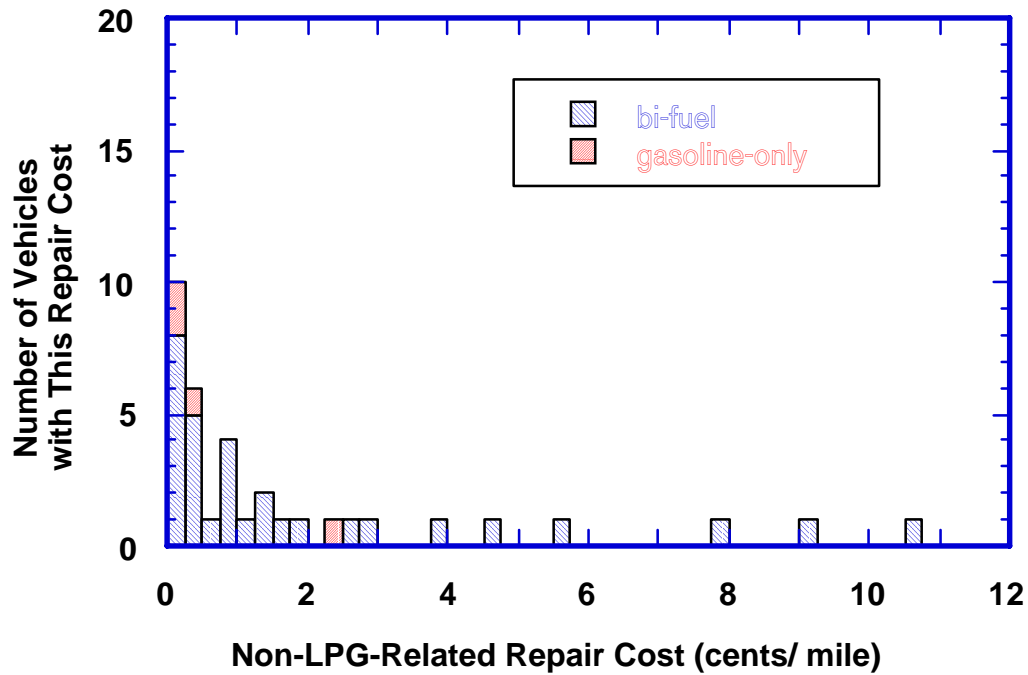


Figure E-1. Distribution of non-LPG related repair costs for the 35 project vehicles

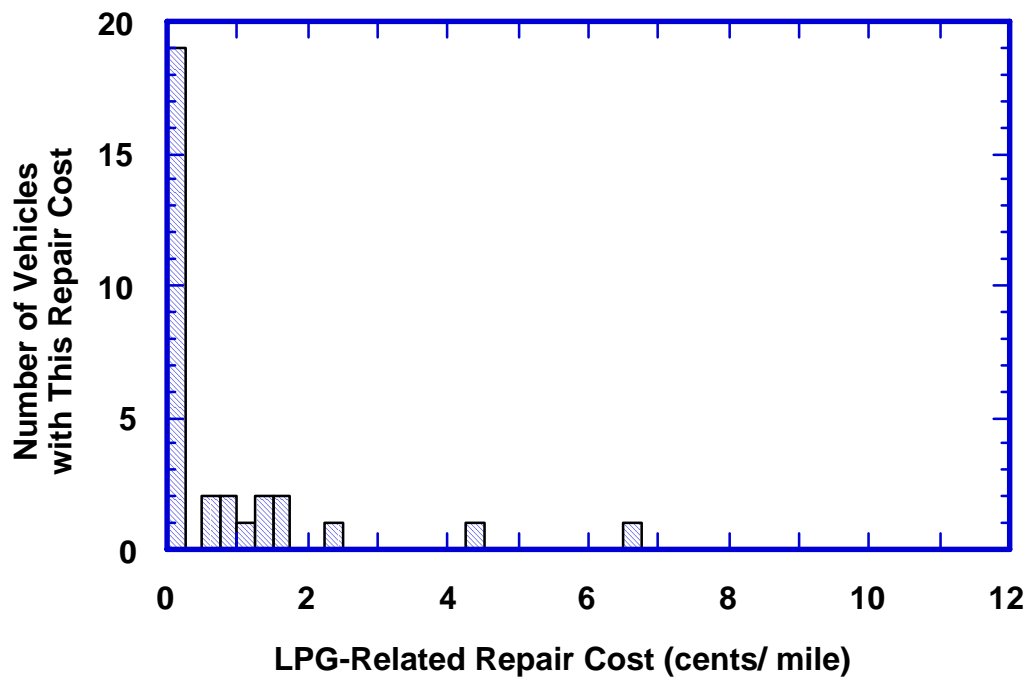


Figure E-2. Distribution of the LPG related repair costs for the 31 bi-fuel vehicles

Reliability

We used the number of unscheduled maintenance occurrences per five thousand miles to evaluate the reliability of the vehicles being studied. The statistical summary is provided in Table E-3. The corresponding data are available in Appendix D.

As was also true for the repair costs, the fact that repairs do not follow a normal distribution means that the statistics that are based upon a normal distribution are not presented in Table E-3. As was done for the repair costs above, the sparsity of the gasoline-only data set was addressed by examining the difference between the LPG-related repair rate and the total repair rate for the bi-fuel vehicles; this is the portion of the repairs that is expected to have occurred even if the vehicle had not been converted to bi-fuel operation. As shown in Figure E-4, six of the 35 test vehicles had a non-LPG-related repair rate between 0 and 0.1 repairs per 5,000 miles whereas 8, including one of the gasoline-only vehicles, had repair rates of more than 1 repair per 5,000 miles. On average, the non-LPG-related repair rate for the bi-fuel vehicles is 0.65 repairs per 5,000 miles. Because this is based upon a much larger sample size than is the mean repair rate for the 4 gasoline-only vehicles, and includes only repairs that were not related to the LPG system, it is estimated that the mean repair rate would be 0.65 repairs per 5,000 miles whether or not the vehicle has an LPG system.

Figure E-4 shows that 18 of the 31 bi-fuel vehicles had an LPG-related repair rate between 0 and 0.1 repairs per 5,000 miles and none had an LPG-related repair rate of more than 1 per 5,000 miles. As also shown in Table E-3, on average the LPG system adds about 0.11 repairs per 5,000 miles to the baseline repair rate. The present finding of 1.1 repairs every 50,000 miles agrees surprisingly well with that from a previous study (Dardalis et al., 1998), which found 1.25 repairs every 50,000 miles, in spite of the small sample sizes in both studies.

As was also true for the repair costs, the estimated means for both the baseline repair rate (0.65 repairs/5000 miles) and the ~15% higher repair rate due to the LPG system (0.11 repairs/5000 miles) have a significant uncertainty but are the best values that can be extracted from the present data. Development of more accurate results requires observation over a longer period (more miles accumulated) and a larger pool of test vehicles, especially gasoline-only vehicles.

Table E-3. Summary of the Statistics for Reliability

	bi-fuel vehicles			gasoline-only vehicles
	overall repairs	LPG related repairs	non-LPG related repairs	overall repairs
	(repairs/5000 miles)	(repairs/5000 miles)	(repairs/5000 miles)	(repairs/5000 miles)
No. of Data Points	31	31	31	4
Mean	0.76	0.11	0.65	0.47

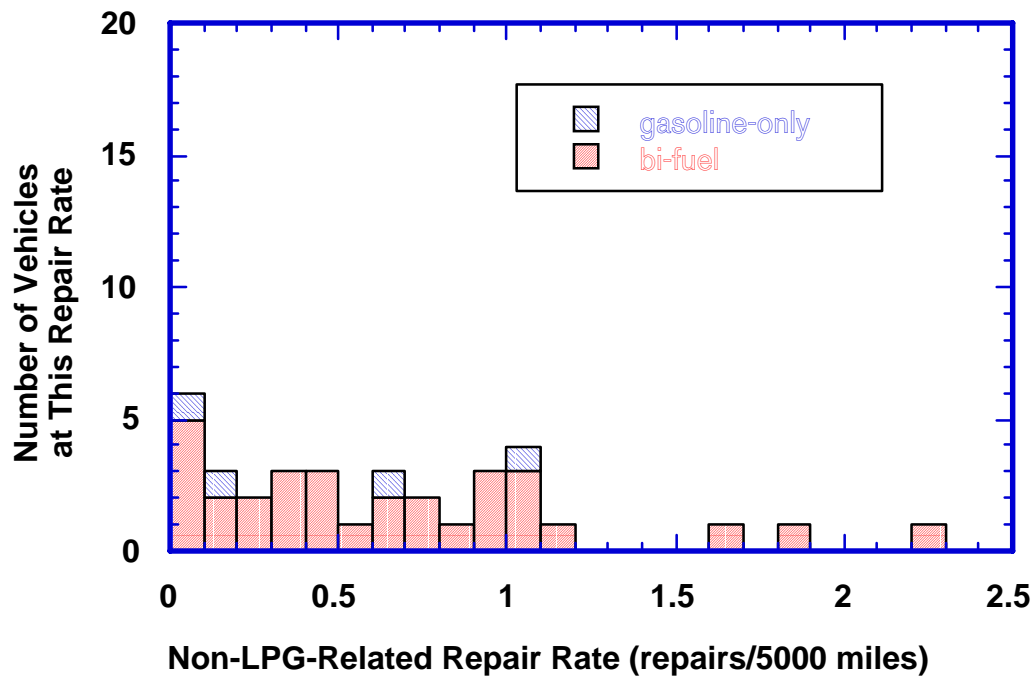


Figure E-3. Distribution of non-LPG related repair rates for the 35 project vehicles

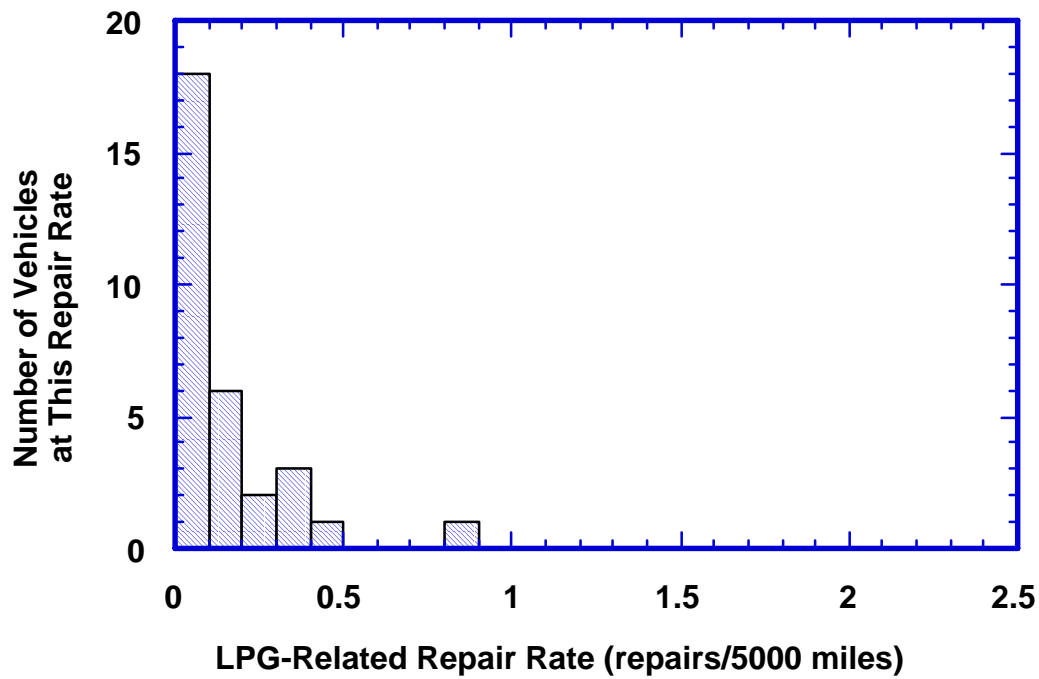


Figure E-4. Distribution of LPG related repair rates for the 31 bi-fuel vehicles

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13. ABSTRACT (Maximum 200 words) Alternative fuels may be an effective means for decreasing America's dependence on imported oil; creating new jobs; and reducing emissions of greenhouse gases, exhaust toxics, and ozone-forming hydrocarbons. However, data regarding in-use fuel economy and maintenance characteristics of alternative fuel vehicles (AFVs) have been limited in availability. This study was undertaken to compare the operating and maintenance characteristics of bi-fuel vehicles (which use liquefied petroleum gas, or propane, as the primary fuel) to those of nominally identical gasoline vehicles. In Texas, liquefied petroleum gas is one of the most widely used alternative fuels. The largest fleet in Texas, operated by the Texas Department of Transportation (TxDOT), has hundred of bi-fuel (LPG and gasoline) vehicles operating in normal daily service. The project was conducted over a 2-year period, including 18 months (April 1997-September 1998) of data collection on operations, maintenance, and fuel consumption of the vehicles under study. This report summarizes the project and its results.				
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